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ORIGINAL ARTICLES.

The Geological Work of the Cambridge Expedition to the East African Lakes, 1930–31.

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FROM November, 1930, till October, 1931, the Cambridge Expedition led by Dr. E. B. Worthington, carried out biological work on the Kenya and Uganda lakes.[1] Owing to a grant from the Royal Society I was able to accompany the Expedition as geologist, with the object of studying the Pleistocene lake deposits and making collections of fossils from them.

At first the Expedition worked on Lake Baringo and Lake Rudolf in the eastern rift valley, and the geological observations concerned with these lakes form the first part of this paper. Later the Expedition moved to the western rift in order to study Lake Edward and Lake George. An opportunity was also taken to visit a part of the Semliki valley. The Pleistocene geology of these areas is dealt with in the second part of the paper.

INTRODUCTORY, WITH PARTICULAR REFERENCE TO THE RIFT VALLEY SYSTEM.

The French geologist, Douvillé, first recognized the extension of the Red Sea faults into Africa, but it was not till after Count Teleki's discovery of Lake Rudolf, that in 1891 Suess showed these fractures to stretch across East Africa as far south as the Zambesi River. Later in 1896, Professor J. W. Gregory suggested the name "rift valley" for a valley formed by the subsidence of a narrow strip of land between two fractures. The term has now been universally accepted for this type of valley, of which that in East Africa is the largest in the world.

The Rift valley of Africa has several branches, the largest of which crosses the Protectorate of Uganda from north to south and is known as the Western Rift Valley. This branch commences at the north end of Lake Nyassa and extends for about one thousand miles, ending near Nimule in the Sudan. Since Gregory's original definition of a rift valley, another theory has been put forward by Mr. E. J. Wayland for the formation of the western branch. This is known as the "Compressional Theory" as opposed to Gregory's "Tensional Theory", for it is the result of the discovery by Wayland, in Uganda, of overthrusting and up-warping in the area through which the rift valley runs. Wayland does not insist that the Kenya rift was formed in the same way as that of Uganda, but it would be astounding could two such similar features, obviously connected in origin, be accounted for by two such diametrically opposed factors.

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[1] A general account of the Expedition's work has been published by E. B. Worthington in the *Geographical Journal,* lxxix, 1932, 275–97, and most of the biological results have appeared as a series of papers in the *Linnaean Society's Journal, Zoology,* xxxviii, 99–362.

The geological work of the Cambridge Expedition deals with the Pleistocene lake deposits of the two rift valleys, and the changes in climate that have taken place during that period, which lead up to the present-day conditions, tending to a still more arid climate.

Where in this paper the term "Pluvial Period" is used, it is taken to mean a time of heavy precipitation of sufficient length to cause a marked change in the form of lakes and rivers, in fact a general increase of precipitation over a very wide area. At present no attempt is made to correlate such changes in climate with the advance and retreat of ice-sheets in Europe.[1]

There were two major Pluvial Periods during the Pleistocene in both the rift valleys, and between them there intervened a time of extreme aridity. Thus the Kamasian and Gamblian of the eastern rift are equivalent to the Kaiso and post-Kaiso of the western rift.

		EAST RIFT	WEST RIFT
	2nd Pluvial	*Gamblian*	*Post-Kaiso*
PLEISTOCENE		Arid Period	Extreme aridity
	1st Pluvial	*Kamasian*	*Kaiso*

A. THE EASTERN RIFT VALLEY IN KENYA COLONY.

I. GENERAL.

This part of the rift valley is, in the main, well defined, and in it lie all the important lakes of Kenya Colony.

The rift originated at a far distant date and recurrent movements have been taking place ever since. Gregory put the earliest rifting as far back as the Jurassic, but more recent evidence has shown that the first movements more probably occurred during early Miocene times. The scarps formed by these Miocene fault lines are now greatly denuded and are in striking contrast to the sharply defined cliffs formed by the more recent mid-Pleistocene movements, on which erosion has hardly had time to leave its mark. This is well seen in the Lake Naivasha district, where the east wall of the old rift valley is probably represented by the Aberdare Range, and the later mid-Pleistocene faulting has formed the cliff-like margin of the Kinangop plateau.

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[1] There can be little doubt that in the future this correlation will be possible.

The Kinangop is formed of a series of lavas and tuffs, of which the upper members were evidently deposited in a shallow lake that had formed on the floor of the rift prior to the second period of major faulting. Since water-deposited tuffs and occasional bands of diatomite occur elsewhere in lower members of this series, it is evident that a lake existed continuously or intermittently for a long time before the upper deposits of the Kinangop plateau were laid down.

A well developed series of lake beds of this period is found in the Lake Baringo area. These were first discovered by Gregory who postulated a much extended Lake Baringo (his Lake Kamasia) [1] in which they were formed. From the name he gave this ancient lake, rocks of similar date throughout the eastern rift valley have come to be known as the Kamasian series. Since Kamasian deposits are found as far north as the northern end of Lake Rudolf [2] and at least as far south as Lake Magadi,[2] one must suppose that during Kamasian times there existed a chain of great lakes, or one huge lake, extending throughout this part of the rift. During the deposition of the Kamasian tuffs the conditions appear to have become progressively more and more arid with the consequent drying up of the lake. Unlike the deposits of similar age in the western rift (Kaiso Series) the entire thickness of the Kamasian Series (so far as is known) is unfossiliferous, with the exception of a few feet of the deposits forming the upper edge of the Kinangop plateau. There Dr. Leakey has found Acheulean coup de poings and other tools having an Aurignacian tendency. Together with these tools were one or two fossils including teeth of *Hipparion* and fragments of *Equus* and Antelope. That these implementiferous horizons should have sustained faulting together with the rest of the Kamasian during the second period of rift valley formation, indicates the very recent date to which this faulting must be assigned. It was these movements that gave the rift floor its present form, characterized by block faulting owing to a series of subsidiary E.–W. faults cutting across the main N.–S. fractures. In consequence of this the whole floor of the rift has not sunk to the same extent. This may be seen when one considers the levels of the lake basins lying in the rift: to the north, Lake Rudolf lies at 1,300 feet, then travelling southwards one finds Baringo (3,200 feet), Hannington (3,300 feet), Nakuru (5,800 feet), and finally Naivasha, the highest lake in the rift valley, lying at 6,200 feet. From Lake Naivasha the floor of the rift valley continues to slope upward, for here the volcano Longonot[1] has built up a great base over which the road rises to approximately seven thousand feet. From here southward the level of the country falls away till at Lake Magadi the height above sea-level is only 2,000 feet.

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[1] *The Rift Valleys and Geol. of E.A.*, p. 114.

[2] Fossils of this date have been known to occur in the Omo Valley for many years. In 1932 Dr. Arambourg, of Paris, collected a large mammalian fauna which is now being worked out.

[3] Observed forming the west wall of the rift valley as far south as Suswa Volcano, and these deposits must continue for some distance to the south.

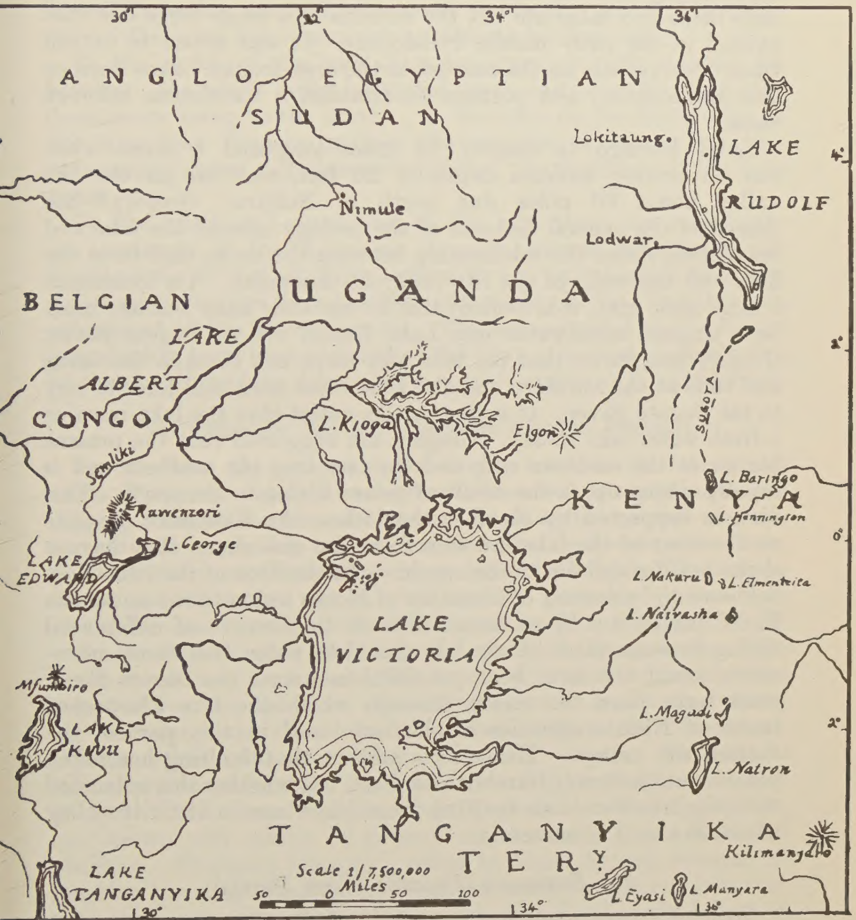

Fig. 1.

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[1] The age of the base of Longonot is problematical and may be post-Kamasian.

II. The Lake Baringo Basin.

Whilst working with Dr. L. S. B. Leakey's East African Archaeological Expedition, 1928–9, Mr. J. D. Solomon[1] established a series of old lake levels around Lake Naivasha and also a similar series surrounding both the Elmenteita and Nakuru basins, thus showing that these two lakes are but the remains of a single large one that existed in the early middle Pleistocene. It was hoped to extend these observations on old beaches to the area around Lakes Baringo and Hannington, and perhaps to establish a correlation between them.

Lake Baringo is roughly 13 miles long and 5 miles wide, has an almost uniform depth of 20 feet, and lies in the rift valley about 60 miles due north of Nakuru. Gregory[2] has described the general features of the geology around the lake and his section shows the relationship between the rocks that form the floor and the walls of the rift valley at this point. On looking at a large-scale map, it is evident that at one time Lake Baringo must have drained northwards into Lake Rudolf via the Sugota River. Gregory has shown that the lake still seeps out through the lavas and tuffs at the northern end and this water must still find its way to the Sugota River. It is due to this outlet that the lake remains a fresh-water lake to-day. Gregory has suggested that the present barrier at the northern end, and the fact that the southern end is rapidly silting up, is the result of recent tilting to the south. This view is supported by the fact that when the Kamasian deposits on the west of the lake are seen from the east shore, they have a slight but decided dip to the south. As the floor of the rift valley is known to be formed of a number of blocks owing to the numerous E.–W. faults, it is by no means difficult to conceive of differential tilting between these blocks. It should be noted that these movements could not have been pre-Gamblian, since the Sugota River must have been the means through which the late Pleistocene fauna of Nilotic affinities established itself in this part of the eastern rift valley. Hence it is certain that faulting has taken place since the lower Gamblian at least, but whether this coincided with the late Gamblian faulting found elsewhere in the rift valley (Naivasha etc.) is uncertain.

(*a*) *Kamasian Deposits* (First Pluvial).

West of Baringo between the lake and the Kamasia escarpment occur the block-faulted series of aqueous tuffs that have given rise to the term Kamasian. These deposits are thickly interbedded with gravels and clays, the former occurring in thick lenses. Where the gravels have been covered by lavas, they have been baked to a hard, red, conglomeratic mass which, when broken up by erosion, forms huge boulders lying in the gullies cut into the deposits. Though an extensive search was made, no fossil remains could be found in any of these beds.

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[1] Dr. L. S. B. Leakey, *The Stone Age Cultures of Kenya Colony*, Appendix A.

[2] Professor J. W. Gregory, *The Rift Valleys and Geology of E.A.*, p. 107.

On the east of the lake, where the Mukutan River leaves the hills, there is a large area of torrential gravels. It seems likely that these are of Kamasian age and correspond to the deposits on the other side of the lake, but it was not possible to confirm this.

To the north of the lake there are aqueous tuffs overlain by basalts ; the whole series is faulted in an east-west direction, the downthrow being to the north. It was here on the north edge of the lake that Gregory noticed the seepage of water into the surrounding lavas and thereby explained the freshness of the lake water.

To the south and south-east of the lake there are apparently no exposures of the Kamasian deposits, except perhaps in the banks of the Ol Arabel River, where it has cut through two lava ridges which appear to be the tops of fault blocks that have become submerged in the lake sediments. The beds exposed are torrential gravels that have been resorted at the top ; this was probably due to the rise of the lake during the second (Gamblian) Pluvial Period.

(*b*) *Gamblian and later Deposits* (Second Pluvial).

On the west the ground slopes evenly towards the lake at an angle of approximately five degrees. The rock is an aqueous ash dipping towards the lake at the same angle as the ground surface, so that it is impossible to see more than the shallowest of sections, and the thickness of these deposits could not be judged. The surface of the ground is here strewn with boulders probably ejected from one of the small group of island volcanoes in the centre of the lake.

To the south-east of the lake, and north of Goymonange, three beach levels may be traced. The lowest of these, little more than 3 feet above the water, is certainly due to a recent fluctuation and therefore cannot be regarded as belonging to the Pleistocene. Of the other two, the higher occurs at between 25 and 30 feet above the lake, and the lower at a height of approximately 15 feet. Both these beaches, but in particular the upper one, are strewn with pieces of pottery and humanly made flakes of obsidian. Professor Gregory[1] refers to these human remains as marking the sites inhabited by Neolithic man, and he remarks that with them occur the shells which at one time lived in the lake. In the area mentioned by him, near the Guaso Arabel, no molluscan remains could be found, but obsidian flakes and fragments of pottery were abundant.

South of Baringo, at a point 4½ miles due east of Njemps Ndogo, there are a few small exposures of lake beds some of which are fossiliferous, but in none of them could implements be found. The diagrammatic section (Fig. 2) shows how the beds occur.

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[1] J. W. Gregory, *The Rift Valleys and Geology of E.A.*, p. 108.

The fossiliferous beds lie unconformably upon an orange-red deposit of tuff which appears to be identical with that found capping the highest of the three beaches that occur to the south-east of the lake. This indicates that there was a rise of the lake to about 100 feet above its present level after the formation of the 25 ft. beach found on the east of Baringo. It therefore appears that these fossiliferous marls and diatomites are to be dated as post Gamblian i.e. Makalian.[1]

The mollusca found in these beds appear to be extinct in Lake Baringo, but still occur in other Central African lakes and the Nile basin. The specimens found include :—

Melanoides tuberculata (Müller).
Corbicula consobrina (Cailliaud).
Corbicula africana (Krauss).
Unio sp. indeterminate.

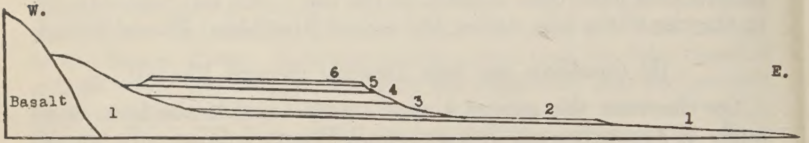

Fig. 2.—Section of Second Pluvial Deposits, south of Lake Baringo. 1 : Yellow-red volcanic ash ; 2 : highly fossiliferous marl ; 3 : marl with kunkar ; 4 : Pure white diatomite ; 5 : Diatomaceous rubble with kunkar. Vertical scale, $\frac{1}{10}$ in. = 1 foot. Horizontal scale, 6 in. = 100 yards (approx.)

III. Lake Rudolf.

Lake Rudolf lies in the northern part of the eastern rift valley, is approximately one hundred and eighty miles long, and varies from 15 to 32 miles in breadth. It lies at only 1,350 feet above sea-level and consequently the climate is extremely hot, whilst the surrounding country is sub-desert with a sparse vegetation of Dom palms and scrub occurring along the watercourses. The rivers are dry throughout the year, except for a few days during the rainy season when they come down as torrents.

At its southern end the shores of the lake rise steeply to about six hundred feet above the water, but on its west shore for a distance of 60 miles north of the Turkwel River, and on the east shore from Alia Bay, as far as the Abyssinian border, there are wide desert regions sloping gently towards the lake.

The Expedition's camp was situated on the west side of the lake at the mouth of the Kalliokwel (Kobua) River.

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[1] L. S. B. Leakey, *Stone Age Cultures of Kenya Colony*, Appendix A.

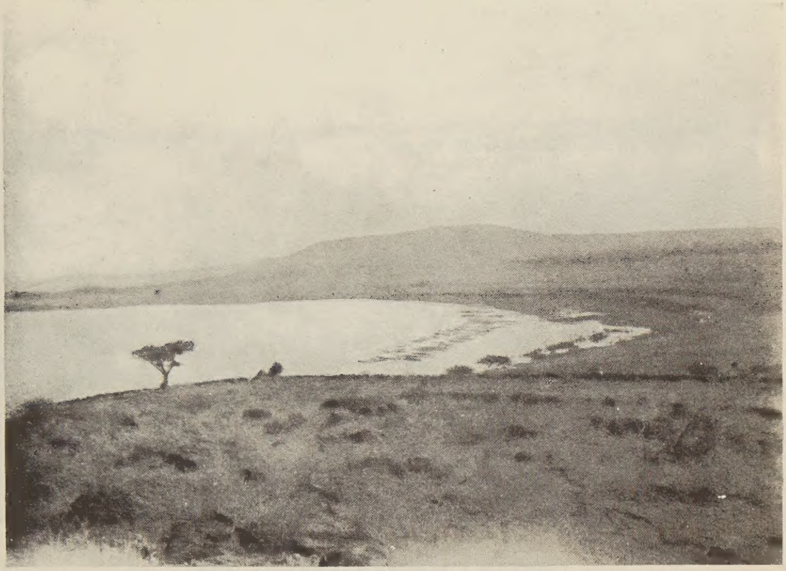

Photo by V. E. F.

FIG. 1.—LAKE BARINGO.
Showing the silting up of the South end.

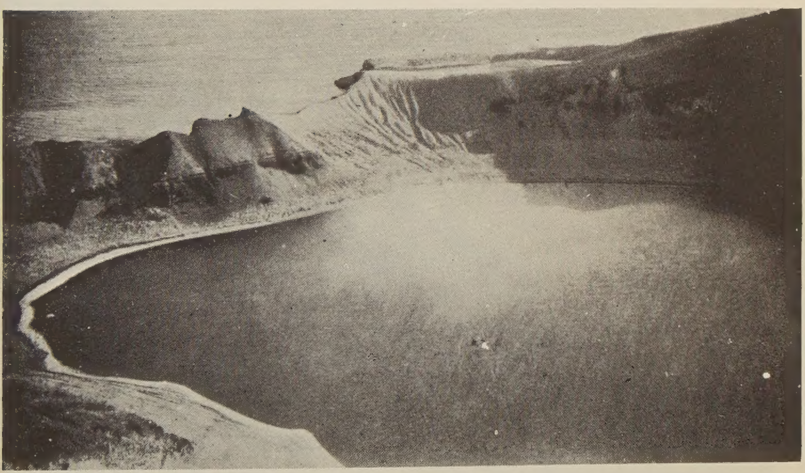

Photo by S. W.

FIG. 2.—LAKE RUDOLF.
Crater Lake B on Central Island.

[*To face p.* 104.

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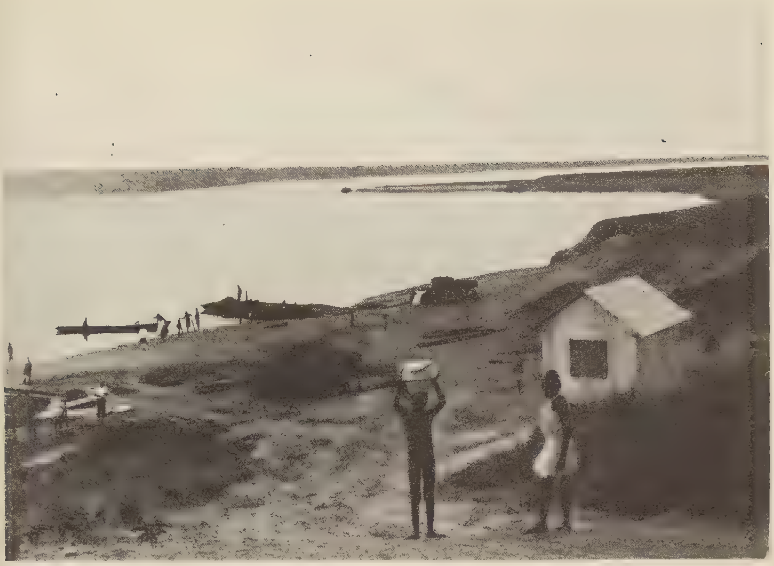

Photo by E. B. W.

FIG. 1.—THE KAZINGA CHANNEL.
Katunguru Ferry.

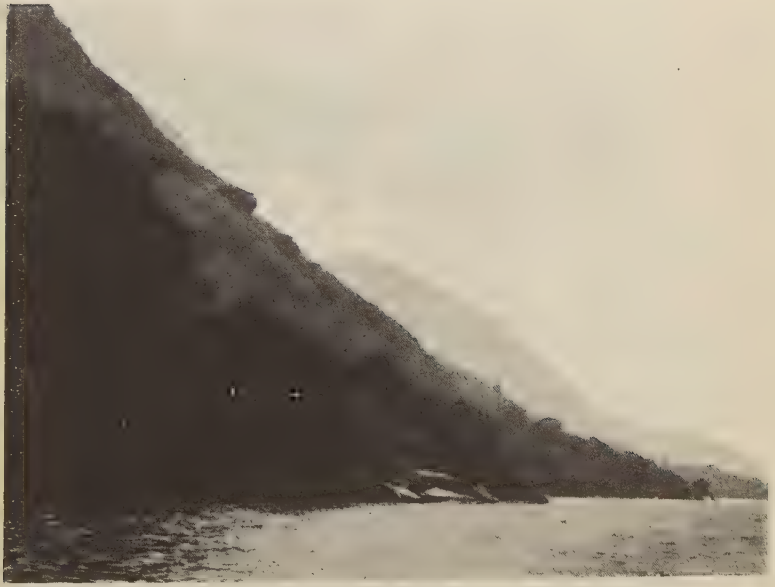

Photo by E. B. W.

FIG. 2.—LAKE EDWARD.
The west fault scarp of the Rift plunging beneath the lake.

(*a*) *The Losodok Hills.*

To the west of the Expedition's camp there was a line of hills (for the most part flat topped) having a general north–south direction. The southern end of the range lies just north of the Turkwel River, whence it stretches northwards for a distance of forty-five miles. The northern end turns west of north in the direction of the Murueris Mountains. The hills are apparently volcanic in origin throughout their length,[1] and there seems little doubt that they follow a fault line. In general the base upon which they are built appears to be a basaltic lava that must have welled out quietly, but was later followed by a period of eruption, during which the main mass of the hills with their eruptive centres, such as Losodok Volcano, were formed. With the tuffs and agglomerates that were then ejected there also occurred some flows of basalt which have given rise to the characteristic flat top of this range of hills.

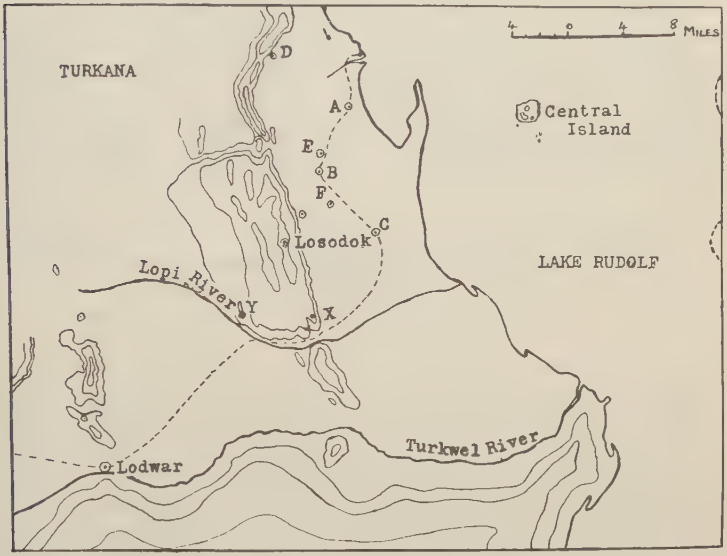

Fig. 3.—A map of a portion of the west coast of Lake Rudolf.

On the north side of the Lopi River pass, the hill marked *X* (Fig. 3) is, at the top, formed of a columnar basalt, in which the columns lie nearly horizontally. Owing to the thickness of the scree it was not possible to ascertain on what this basalt rests, but near the base there appeared to be a lake deposit outcropping through the scree which yielded some small fragments of highly fossilized bone.[1]

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[1] At two points it appeared that sedimentary beds occurred amongst the volcanic series, but if this were the case they were so disturbed and altered by the volcanic activity as to be unrecognizable.

From the top of the hill X looking northwards, several more or less parallel lines of a red-yellow colour could be seen stretching towards Losodok. These must almost certainly be recently active fissures of a similar nature to those which will be described later from Central Island.

Just before entering the Lopi River pass from the west, on the north side of the track at the point marked Y (map), there is a small line of hills about 30 to 40 feet in height, formed entirely of a pure limestone. This limestone has a curious honeycomb formation giving it a scoriaceous appearance. Its presence cannot be explained in any other way than by supposing it to be a calc-tufa deposit from hot springs that accompanied the volcanic activity.

At points along the eastern edge of the range there is evidence of renewed faulting subsequent to the formation of the hills. At *H* (map, Fig. 3) the junction between the lake beds and the volcanic rocks of the hills is marked by a vein of calcite about 1 foot in thickness and some hundreds of yards in length. There are also dolerite dykes, but these were so weathered that it was impossible to obtain a hand specimen. It is noticeable that whereas the lake beds that occur here are quite undisturbed, all the volcanic rocks have been dislocated. On the west the base of the range of hills slopes gently away, where the lavas have flowed out over the plain; on the east, on the other hand, it is sharply truncated, the lake beds coming right up to the foot of the hills. It seems, then, that after the Losodok range of hills was formed, there was a renewal of the faulting accompanied by the intrusion of dykes. By this faulting the edge of the basal lavas on the east of the hills was cut off, and now lies buried beneath the lake beds.

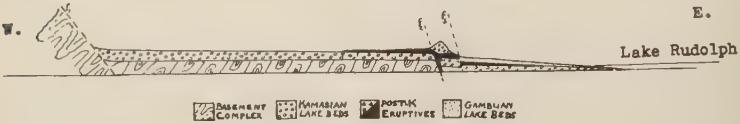

Fig. 4.

In the section (Fig. 4) the supposed relationship of the volcanics, faulting, and lake beds is shown. To the west the lake beds abutting on the rift wall are considered to be Kamasian, since the lavas from the Losodok range flow over them from the east, and these lavas must certainly be of Middle Pleistocene age. On the east side of the volcanic ridge the Gamblian beds are shown banked against the fault face that truncates the basal lavas. These beds must have been deposited during a rise of the lake in late Gamblian times. Finally, during the retreat of the lake, the shore-line deposits were formed which are now found on the slope of the lake beds between the Losodok range and the present lake shore.

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[1] The exact relation of the sandy material from which the bone was obtained to the rocks forming the hill and the scree of columnar basalt fragments was, at the time, impossible to determine.

(*b*) *The Lake Deposits.*

The whole of the area between the Losodok range and the lake shore is covered by lake deposits which still retain their original form, showing the sandspits and bays of old shore-lines. These beaches are of Gamblian or later age, as is shown by the molluscan fauna that they contain. As no marked line of beach formations could be traced at any particular level, it seemed at first that the period of comparative aridity that occurred between the Gamblian pluvial maxima had no effect upon the level of this lake. Later the discovery of derived fossils, mainly fish and mammal bones, but also small boulders containing mollusca in the uppermost deposits, showed that after the establishment of the Gamblian lake, there had been a temporary retreat of the water-level. Whether this corresponded to the period of comparative aridity between the Gamblian maxima, or to the dry period, found elsewhere in the eastern rift valley, between the end of the Gamblian and the Makalian wet phase, is uncertain. As no trace of the origin of these derived fossils could be found it is concluded that the beds from which they came were later completely covered by the Upper Gamblian or Makalian deposits.

The points at which fossils were found are shown by capital letters on map, Fig. 3.

At A a few shells occurred, but no definite fossiliferous band could be found.

At B there were several fossiliferous bands; but none of these appeared to be continuous over more than 40 or 50 yards. Here also were found numerous fish bones which occurred along definite horizons. There were also occasional fragments of mammalian bones.

At C no fossils were found, but there was a flat topped delta deposit containing boulders up to 12 inches in diameter. The original form of this delta has been altered by the erosive action of flood waters from the hills behind.

At D, where there is a depression in which flood water apparently collects for a short time during the rains, there were numerous scattered mollusca.

At E were found a number of shells *in situ* and also numerous rolled mammalian and fish remains presumably derived from the Lower Gamblian.

At F there is an oyster bed formed of *Aetheria elliptica*, which must have flourished on the delta when the lake water was sufficiently alkaline to precipitate any calcareous material brought down by the river. This is concluded from the fact that the oyster bed is mainly composed of large boulders that have formed round a nucleus of one or more *Aetheria* shells. That the shells were living at the time that this precipitation took place is shown by many of the boulders having oysters growing up on their surfaces. Associated with the oyster bed are all the other species of mollusca that are found elsewhere in the lake deposits. This precipitation of calcium carbonate at that time indicates that even when the lake was 200 feet higher than at present the water was highly alkaline.

Of the fossils collected from the Gamblian deposits of Rudolf the following have been identified :—

Fish.
- *Lates* sp. probably *niloticus* — Vertebrae, dorsal spines and pectoral girdles.
- *Synodontis* sp.

Mammals.
- *Hippopotamus* cf. *imaguncula.*
- *Phacochoerus* sp.
- *Antelopes ?*

Reptiles.
- *Crocodilus* sp.
- *Erionyx* sp.

Mollusca.
- *Melanoides tuberculata* (Müller).
- ,, ,, ,, — Slender race.
- *Bithynia connollyi* (Gardner).
- *Cleopatra pirothi* (Jickelli).
- *Planorbis adowensis* (Bourguignat).
- *Coelatura egyptiaca* (Cailliaud).
- *Unio teretiusculus* (Philippi).
- *Corbicula africana* (Krauss).
- ,, *consobrina* (Cailliaud).
- *Aetheria elliptica* (Lamarck).

Since the whole of this molluscan (?) fauna is to be found in the Nile basin to-day it follows that there must have been some connection between the Nile and Lake Rudolf, and further, that that connection must have been established at the latest by the beginning of the Gamblian period. At that time Lake Rudolf was at a much higher level and it seems probable that it had an outlet westwards from the Sanderson Gulf across the Turkana plains and into a lake which then existed in the south-east corner of Anglo-Egyptian Sudan. It is likely that it was from this lake that the Sobat River then had its source and that the lake, which gradually shrank to a marsh and finally dried up, was the link between the Nile and Lake Rudolf. The huge area of black cotton soil which now covers its site has been referred to by Major Athill[1] as the place where " the rivers come to die ".

(c) *Central Island.*

This island had not previously been visited, but from the lake shore we had imagined it to be of volcanic origin. This proved to be the case, it being formed entirely of lavas and tuffs. There are fifteen craters in all, some large, some small, but all still recognizable as distinct explosion centres.

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[1] Major L. F. Athill, *Geogr. Journ.*, 1920, p. 365.

The island is roughly rectangular in shape,[1] its maximum length from north to south being just over three miles, whereas its breadth is approximately two and a half (map, Fig. 5). Its greatest height is 600 feet at a point on the south-east wall of crater lake B. To the north the island is bounded by steep ash cliffs that drop sheer into the lake. Along that shore there is an indentation of the coastline which is really part of the wall of a crater, the remainder being submerged. To the north-east and east lava cliffs form the shore, and this lava apparently forms the base on which the cones of agglomerates and tuffs that form the main mass of the island are built. Here and there the lava has been undermined by wave action resulting in the formation of blow-holes and low cliffs. The southern

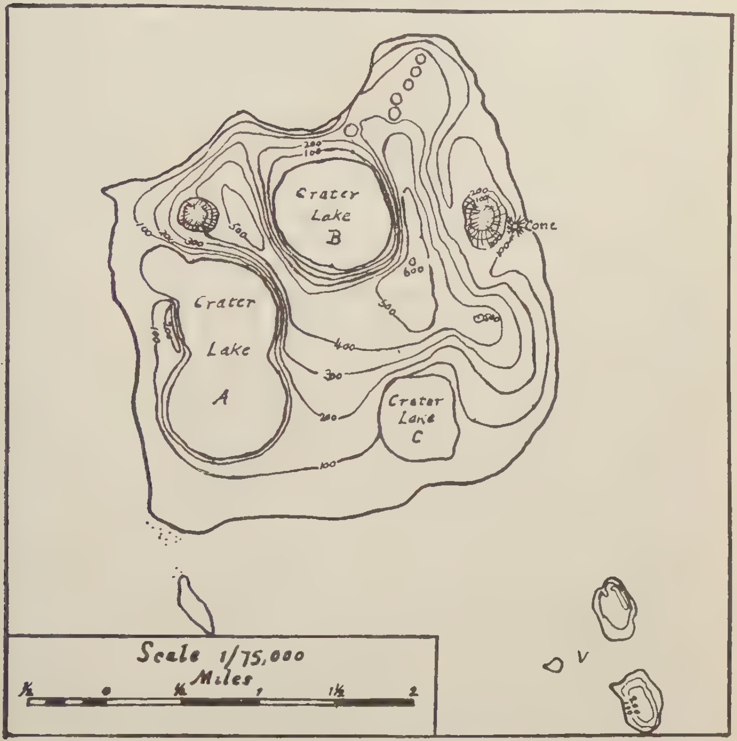

Fig. 5.—Central Island.

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[1] A map of the island by S. Worthington appeared in *Quart. Journ. Geol. Soc.*, lxxix.

and western shores of the island are composed of black, sandy beaches formed of volcanic material.

Volcanic activity on the island still exists in the form of fumaroles. These were found on the sloping ground to the east of crater lake B where the hillside was dissected by a system of fissures each several yards in width. Much of the ground and the boulders strewn over its surface were reddened by oxidation, and in the immediate vicinity of the fissures was warm and damp. The crust over the actual fissures appeared to be formed largely of sulphur and other salts. The main fissure, the highest on the slope of the hill, runs north and south, but at its northern end turns off towards the east. The trend of this fissure is then produced by a row of five small craters, the two most westerly containing active sulphur vents which were both throwing up a spray of sulphur. Each crater is 30 to 40 feet deep, and the walls of the two containing active fumaroles are yellow with a deposit of sulphur. The three other craters in this line are no longer active and show no sign of having had a fumarole stage. The whole group appears to be of more recent origin than others on the island, since round their edges there was fresh ropy lava and scoria that showed no signs of weathering and the form of the craters was unaffected by erosion.

At the foot of the slope on which the fissures occur, and also below the line of craters, there is a dry stream bed which, at its lower end, forms a gorge about 30 feet deep and 25 to 30 feet wide, winding towards the north-east point of the island. In its course the gorge affords a section of approximately 200 feet of tuffs lying upon a base of olivine-basalt. At an earlier stage in the formation of the island there has evidently been a period of fumarolic action, for near the base of these tuffs there is a horizon that contains a large percentage of free sulphur. Immediately below this there lies a bed of large boulders reddened by oxidation in the same way as those now to be seen on the hillside. This would seem to point to two stages in the formation of the island ; first, the extrusion of lavas followed by a short phase of explosive action which died down to a fumarolic stage ; then, after a period of inactivity, a further series of outbursts that gave the island its present form and which has in its turn become reduced to the fumarole stage.

From the lake the cliffs on the north of the island are seen to be covered by a thin coating of fine, light-coloured ash that must have been blown out by the very last eruption that took place.

Evidence of Fluctuations of Lake Rudolf on Central Island.

To the north-east of the island at a height of 30 to 40 feet above the lake there is a series of small cliffs a few feet high together with one or two blow-holes, which must have been formed when the lake was at a higher level. This old shore-line is marked by the occurrence of drift wood (up to the size of palm trees) together with palm leaves and grass. Their occurrence points to a very recent retreat of the lake from this level, since, even in an arid climate, decay cannot be at a standstill.

Along the southern shore this old beach occurs again, but is here accompanied by two lower levels at approximately 20 and 15 feet above the lake. All three beaches are marked by banks of loose material built up by wave action.

There are three small crater lakes on the island, which are marked A, B, and C, in map, Fig. 5. Lake A has been formed by the confluence of three craters. The cliffs of tuff rise to a height of between 300 and 400 feet on the north-east and between 100 and 200 feet on the south and west. The lowest point of the separation of crater lake A from Lake Rudolf is at the north-west corner, where there is a low, rounded ridge about 20 to 30 feet high.

Lake B is almost circular and is formed from a single crater ; it has high walls all round, but to the north it is only separated from Lake Rudolf by a knife-edge ridge some 200 feet high (see Plate V below).

Lake C has high walls on three sides, but is separated from the main lake on the south side by a sandy bank only 10 feet high. The waters of the three lakes, A, B, and C, are far more alkaline than that of Lake Rudolf, and of the three, B is the most, C the least alkaline, indicating that they have been successively cut off from the main lake in the order B, A, C. This isolation of the crater lakes was due to the falling of the level of the water in Lake Rudolf. The order in which they were isolated was determined by the height of the lowest part of the wall of each crater, and was B, A, C, which agrees with the order already indicated by the relative alkalinity of the lakes. All three lakes were estimated to lie at the same level as Lake Rudolf itself, which was to be expected as the tuffs that form their walls are so porous that there could scarcely be a perceptible slope in the water-table between the crater lakes and lake Rudolf. The only reason that the other craters on the island are dry is that their floors lie above the level of Lake Rudolf.

From the type of lavas and the freshness of the craters, together with the occurrence of active fumaroles, the island appears to be of comparatively recent formation. It seems probable that it was first formed at the time of the eruption of the Losodok Hills. That it probably had two main periods of eruption is indicated by the evidence of former fumarole action, already referred to. It may be that the second phase of action was associated with the final movements in the area, i.e. those which caused the truncation of the eastern edge of the lavas of the Losodok Hills.

That the island has recently acquired its present form is shown by the fact that no beaches occur on it at a greater height than 40 feet above the water. From the evidence on the west shore we know that Lake Rudolf has fallen steadily from more than 250 feet above its present level. It therefore seems that the final eruptions on the island took place when the water-level of Lake Rudolf was only 40 feet higher than it is to-day, and thereby obliterated any other beaches there may have been. If it were permissible to use the only time scale available, i.e. that afforded by the Lake Nakuru basin, where the lake is known to have fallen 145 feet in the last three thousand years, one could, by allowing for the difference in size of the lakes, estimate that these final eruptions took place about one thousand years ago.

(*d*) *North Island.*

Unfortunately the expedition was unable to visit this island, but in 1931 Mr. Whynne Harris crossed to it, and judging from a few specimens and the description received from him, this island is also of volcanic origin. The island is formed of one or more ash cones, with which there appear to be associated some lavas.

As a result of these observations in the eastern rift valley one sees that volcanic activity has been reduced to such an extent as to be almost non-existent, whilst the area is becoming increasingly arid from lack of precipitation, with the consequent shrinking of the lakes and rivers. Large areas of country have already become uninhabitable by any but nomadic people, and if the present conditions are continued for the next one or two centuries all but the highlands over 7,000 or 8,000 feet will have become sub-desert in character.

In the next part of this paper dealing with the western rift valley a similar sequence of events will be traced, showing that there also, during the Pleistocene, the conditions were similar to those of the eastern rift.

(*To be continued.*)

Notes on the Amazon.

By R. L. Sherlock, D.Sc., A.R.C.S., F.G.S.

So little is known about the geology of the Amazon that it seems worth while recording a few observations made during a recent journey up that river.

Everything connected with the Amazon is on a gigantic scale. The length is about 4,000 miles, the drainage area is 2,368,000 square miles, and several of its tributaries are rivers of the first magnitude. The Amazon is navigable for ocean steamers as far as Iquitos, in Peru, 2,300 miles from the Atlantic. On the Peruvian frontier the river is already 2 miles wide and above the so-called delta it is from 40 to 50 miles wide.

It is a remarkable fact that the greater part of the Amazon basin has only a slight elevation above the ocean. Church (1,[1] p. 382). gives the river elevation at Obidos, 523 miles above Para, as 6 feet,

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[1] The figures in parentheses refer to Bibliography at end of article.

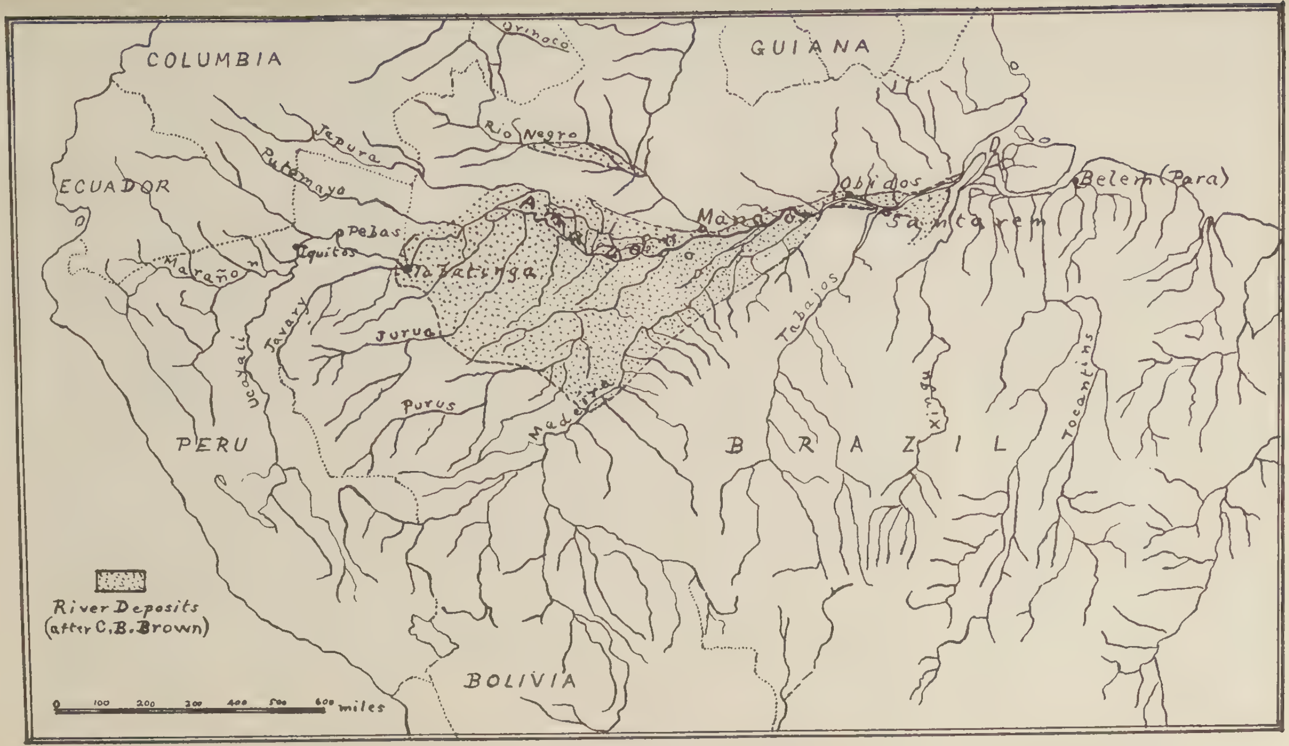

FIG. 1.—Map of the Amazon Basin.

and at the mouth of the Javary, over 2,000 miles from the ocean, as 36 feet. Other estimates differ considerably but all agree in the smallness of the elevation. Nevertheless the river current is rapid; the average being 3 miles an hour, and in places the velocity reaches 5 miles an hour. This is due to the great depth of the river which at flood-time averages 120 feet (Todd in 1, p. 380). At Obidos the river contracts to rather over a mile wide and a sounding there gave 348 feet (2) with a surface velocity of 4 to 5 miles per hour. The tides, which are from 10 to 14 feet high, are felt as far up as Obidos. At the close of the rainy season the river has risen in some parts from 40 to 50 feet above low-water level. It then carries an immense quantity of drift wood, much of which sinks, waterlogged, to the bottom.

Another remarkable fact is that the Amazon has no real delta; all the vast volume of detritus brought down is washed away by a tidal bore and the ocean is said to be gaining on the land (1, p. 385).

All through Brazil and into Peru the banks of the Amazon are low and, where visible through the foliage, are composed of clay and sand. Brown (3) gave an account of the geology of the basin and described a great expanse of old river deposits extending, roughly, for 950 miles westward from a point about 146 miles west of Para, and with a maximum width of 400 miles. A modern alluvial flat is sunk into this plain with a width along the main river of about 30 miles, and extending up the tributaries. In the flood season the lower flat is flooded.

Branner (5) speaks of the Amazon basin as occupying a synclinal fold commencing in Para State and extending along the valley axis at least as far as Manáos. In this fold Palaeozoic beds rest on Pre-Cambrian rocks and dip gently to the axis. Branner, on his map, has expanded Brown's alluvial flat to a width of about 70 miles at the expense of the late river deposits, and has mapped the rest of these as Miocene or Pliocene; but in the text (5, p. 230) he mentions that large tracts of his Miocene are really alluvial.

Between Obidos and Manáos the continuity of the forest is occasionally broken and field-glasses show variegated sediments. Red is the prevailing colour, with brown, orange, white, crimson, and lilac. The appearance is that of the Bagshot Beds. At Santarem, at the mouth of the Tabajos, the bluff, here about 40 feet high, was visited and showed a section of about 15 feet consisting of thick soil and subsoil over dull pinkish loamy sand with spots and streaks of white clay. Flat bedding is shown in the lower part. Attached to the bluff is about 5 feet of sand and gravel made of the same ingredients. The pebbles are of ironstone composed of deep red cemented sand-grains, and the deposit is evidently a fragment of river gravel. At some localities the sand is cemented into sandstone. At Tarumba Falls, near Manáos, there is a pure white variety, and the streets of Manáos are paved with a hard red non-calcareous sandstone.

The Amazon basin is almost free from earthquakes, although a resident at Manáos remembered one slight shock during the last twenty-five years.

Several windmill pumps are seen at Santarem and, according to a former resident, they are about 80 feet deep and obtain good water.

The first strata met with known, by fossils, to be Tertiary crop out west of Sao Paulo, which is 1,350 miles west of the mouth of the Amazon and 150 miles below Tabatinga.

According to Brown, all the variegated sands and clays seen east of Sao Paulo are Quaternary and unconformable to the bluish Tertiary clays. The junction is said to be denuded, but as sections are few and obscured in all cases by landslips (4, p. 77) the erosion may not be of great significance.

At Sao Paulo, Brown noted 60 feet of Tertiary strata, including 50 feet of greyish and greenish-blue and dull purplish clay with impure lignite beds. The strata rested on 10 feet of bluish arenaceous clay with calcareous nodules. Below Sao Paulo may be seen at low water brownish-green clays with leaves. These clays are replaced at Obidos by sandstone, but it is uncertain if they also are Tertiary.

The Tertiary rocks appear from their characters and fossils (6, 7) to be of fluviatile, or possibly brackish-water, origin, and, as they extend below low-river level to an unknown depth, their is evidence that the Amazon basin has been sinking since their formation (and long before). The thickness of Quaternary deposits resting on them is, according to Brown, not less than 300 feet in some places. The inference is that the basin has been sinking for a long period. The absence of a delta, the annual flooding of the modern alluvial flat, the fact that the bottom of the river is well below ocean-level right through Brazil, and the extremely low gradient of the river, all indicate that sinking is still in progress. It appears, at first sight, that the Amazon is just succeeding in keeping itself from being flooded by the ocean, and that a small depression of the basin would cause it to be flooded over a vast area extending into Peru.

Probably, however, a moderate depression, say of 50 feet, would merely turn the Amazon into a succession of lakes. The flow of water is five times that of the Mississippi and such an enormous volume of fresh water finding its way to the ocean would lead to the formation, first, of lakes and then of one large lake above Obidos. If depression continued there would eventually be formed a kind of Gulf of Bothnia in which the water would be brackish.

A. L. du Toit has pointed out (8, p. 108) that, under the "Displacement Hypothesis", the rivers of South America have suffered a reversal of drainage. When South America joined Africa the rivers that now enter the Atlantic must have flowed toward the Pacific, but with the rise of the Andes across the outlets of the rivers (as a result of continental drift) the rivers must have been compelled to find their way into the Atlantic. The Amazon offers evidence for this hypothesis, for it will be noticed that the river deposits, as shown by Brown (see Fig. 1), resemble in outline an inverted delta. The rise of the Andes would dam up the ancient river into a lake which would eventually find an outlet eastward, as at present.

The Amazon is mentioned (e.g. 9, p. 669) as one of the few rivers carrying red mud to the sea, and this is ascribed to the lateritic soil produced in a tropical climate. As the strata, where seen, are mostly red coloured their denudation would produce red mud, even if the modern soils were not lateritic. No doubt these strata were themselves produced under continental conditions, but the red character of Amazon detritus may be due primarily to denudation of red strata rather than to destruction of present-day red soil.

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The Age of the Highest Coal Measures in West Pembrokeshire.

By A. E. Trueman.

THE westward extension of the South Wales Coalfield in Pembrokeshire is of complicated structure and the sequence is very imperfectly known. This is particularly true of the west of the county, where the coalfield has been very little worked for many years. In the eastern portion of the county, between Haverfordwest and Carmarthen Bay, the Coal Measures consist mainly of shales which have been correlated with the Lower Coal Series of the main part of the South Wales Coalfield[1] and which are not higher than the Pulchra Zone.[2]

In Western Pembrokeshire, along the shores of St. Bride's Bay, a similar shale group is succeeded by a group in which sandstones predominate. The shales are referred to the Ovalis, Modiolaris, and

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[1] "The Country around Haverfordwest," *Mem. Geol. Surv.*, 1914, 156.

[2] T. N. George and A. E. Trueman, "The Correlation of the Coal Measures in the Western Portion of the South Wales Coalfield. Part IV: The Coal Measures of East Pembrokeshire," *Proc. S. Wales Inst. Eng.*, xli, 1925, 415.

Similis-Pulchra Zones on the evidence of fossils collected by members of the Geological Survey between Broad Haven and Little Haven.[1] The age of the higher beds has been in some doubt.

De La Beche suggested in 1846 that in part these strata were to be correlated with the Pennant Sandstones of the main area of the Coalfield. In support of this view the officers of the Geological Survey more recently drew attention to the great thickness and to the lithology of the Coal Measures in West Pembrokeshire.

The thickness is probably over 6,300 feet[2] as compared with not much more than 1,300 feet in the east of the county. A comparison of these thicknesses with the total of approximately 8,000 feet for the whole of the Coal Measures near Swansea would appear to indicate that some part of the Pennant Sandstone is represented in West Pembrokeshire, although the rapid westward expansion of the strata in the main part of the coalfield emphasizes the need for caution in interpreting thicknesses. As regards lithology, the

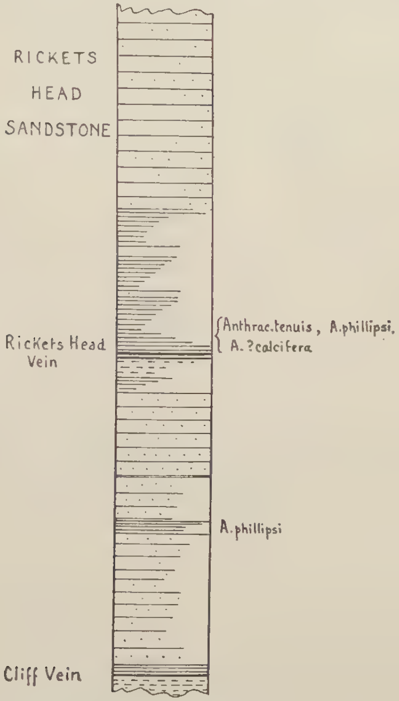

FIG. 1.—Generalized Section in the Upper Portion of the Coal Measures near Nolton Haven. Approximate scale: 1 inch to 300 feet.

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[1] "The Country around Milford," *Mem. Geol. Surv.*, 1916, 119.

[2] Ibid., 114.

Survey officers pointed out the occurrence of many " pennant-like sandstones " [1] in the higher strata of West Pembrokeshire.

This correlation was not put forward with any confidence by the Survey officers, however, owing to the conclusions of R. H. Goode, which were published just before the memoir referred to. Goode had investigated some Upper Carboniferous floras in Pembrokeshire, including plants collected at high horizons in the Coal Measures near Nolton Haven ; he concluded that all these were of Middle Coal Measure (Yorkian) age, and that they could not " be regarded as belonging to the Pennant Grit " since " no plants occur which are not found at a lower horizon than the Transition Series ".[2]

In the course of recent work on the coast near Nolton Haven fossils have been found at a number of horizons, including some shells which fix the general age of these shales. It is not proposed to discuss the palaeobotanical aspects of the correlation ; it is sufficient to note that this was not the only unfortunate (nor the most misleading) conclusion resulting from Goode's work in Pembrokeshire. Dr. Emily Dix, who has lately re-examined Goode's specimens in the Sedgwick Museum, as well as those from the same area in the Museum of Practical Geology and some collected by the writer, points out that the floras represented undoubtedly include some newer than the so-called Yorkian.

The shells found in these higher beds occur at two horizons. The first of these is seen in Nolton Haven, on the south-eastern side, a short distance south of the Chapel (Six-inch map, Pemb. xxvi, N.E.) where a band of dark shales occurs amongst the sandstones. The shales contain numerous badly-preserved shells which are referred to *Anthraconauta phillipsi* (Will.). There is little doubt that this horizon is above the Pulchra Zone.

The second horizon is a group of shales associated with the Rickets Head veins, which can best be examined at low water in the angle of the cliffs on the south side of Rickets Head (Six-inch map, Pemb. xxi, S.E.). Shells occur at several levels in the shales. They include *Anthraconauta tenuis* (Davies & Trueman), *A. phillipsi* (Will.), and some small forms which resemble *A. calcifera* (Hind). These shells indicate the Tenuis Zone and the strata represented may therefore be correlated with the upper part of the Pennant Series.

It is not possible to suggest the limits of these zones, but it is apparent that the Coal Measure sequence near St. Bride's Bay is comparable in general character with that of the main part of the South Wales Coalfield.

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[1] Ibid., 114.

[2] R. H. Goode, " On the Fossil Flora of the Pembrokeshire portion of the South Wales Coalfield," *Quart. Journ. Geol. Soc.*, lxix, 1913, 270.

Notes on The Geology of the Lower Amazon.

By D. M. Reid, Dept. of Biology, Harrow School.

(PLATE VII.)

THE following notes were made while on an expedition with Mr. J. T. Cunningham (financed by the Trustees of the Percy Sladen Trust and the Royal Society) to the Island of Marajó in the mouth of the River Amazon. The object of the expedition was not geological so that it was not possible to carry out an extended survey of the district explored.

The area under discussion is perhaps best described as the open land in the neighbourhood of the city of Belem (Pará) and a large part of the east side of the Island of Marajó. (See map, Fig. 1).

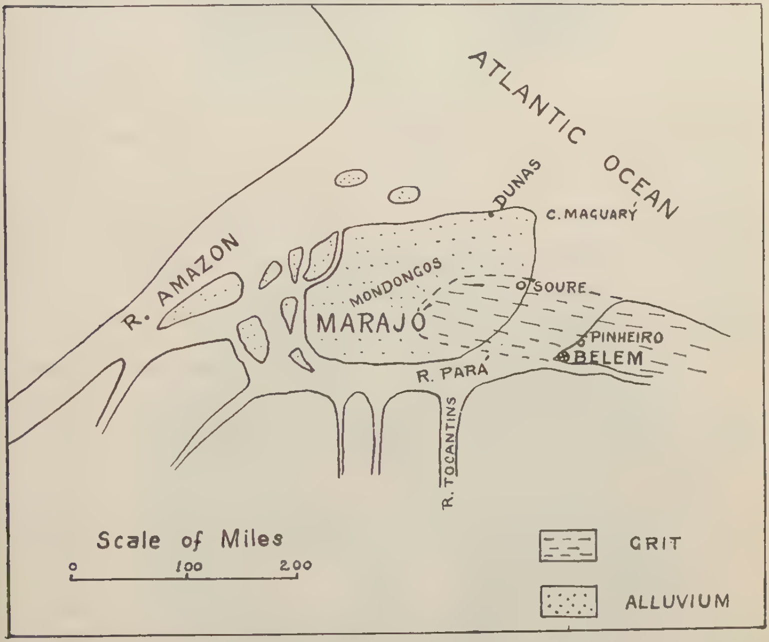

Fig. 1.—Sketch-map of the Lower Amazon, somewhat diagrammatic.

Generally speaking, the whole of this country is a flat alluvial plain. Around Belem the country appeared undulating but it was so densely covered with forest that only a general impression could be got of its surface peculiarities. Therefore information was sought in the areas cleared by Indians, but since they choose such places because of the depth of the soil the results were not helpful. However, at one place close to the city boundary on the Pinheiro road a shallow quarry had been dug to get at the only rock available for road making.

This rock is red in colour and is very friable. It occurs in the form of concretionary boulders of all sizes and shapes each penetrated by numerous cavities and traversed by holes. (See Plate VII, Fig. 1.)

Although a search was made a good way into the forests and the coast examined where possible only occasional boulders of this rock were found, the decaying vegetation from the trees or the deep deposits of mud on the shores having completely covered all exposures.

At the town of Soure on the east side of the Island of Marajó the cliffs at the east end of the town are composed of a rock which is so similar in appearance as to be undoubtedly part of the mainland bed. On examination a section of the rock shows it to be composed of grains of quartz cemented together by iron oxide. The quartz grains are of irregular size varying from 0·1 mm. in diameter to 0·6 mm. The outline of these grains varies from definitely rounded forms to those with acute angles, such a mixture is very unusual and almost inexplicable in this case.

The amount of iron oxide also varies greatly (as can be seen in Plate VII, Fig. 2). This irregular distribution of the cement would seem to confirm the belief in the youth of this bed, for, as Willard (1)[1] has pointed out, young geological formations are often very irregularly cemented. There was a loss of 63·7 per cent by weight of the rock when treated by acid, of this 22·8 per cent was found to be iron.

After dissolving out the iron it was found that the greater number of the quartz grains had lost their rounded form and had assumed shapes of great irregularity with many re-entrant angles. All these irregular grains were much discoloured by iron, so it may be concluded that iron was present in the quartz as well as in the rock in the form of cement.

Perhaps it is the great relative quantity of the cementing iron oxide which is unusual. A glance at the photograph on Plate VII, Fig. 2, will illustrate this.

The Island of Marajó differs from the mainland of Belem in that it has a definite wet and dry season whereas on the mainland there is rain practically every afternoon in the dry season. This can be correlated with the dense mainland forest and the more open land on the island. Therefore, it is comparatively easier to get a clear idea of the country on the island than it is on the mainland. The conglomerate which occurs at Soure passes inland and forms the backbone of the island. To quote from the *Boletim du Museu Goeldi* (2) " The structure of the Island of Marajó is very simple. It consists of two formations, modern alluvium and an older series corresponding to that of the neighbouring land of Pará.

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[1] The numbers in parentheses refer to Bibliography at end of article.

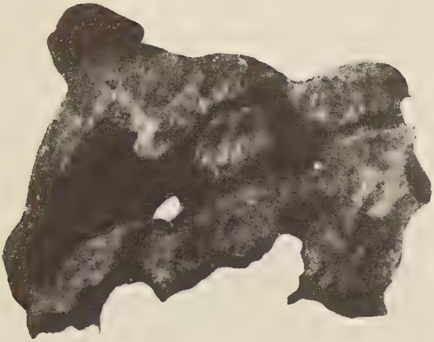

FIG. 1. × $\frac{2}{3}$.

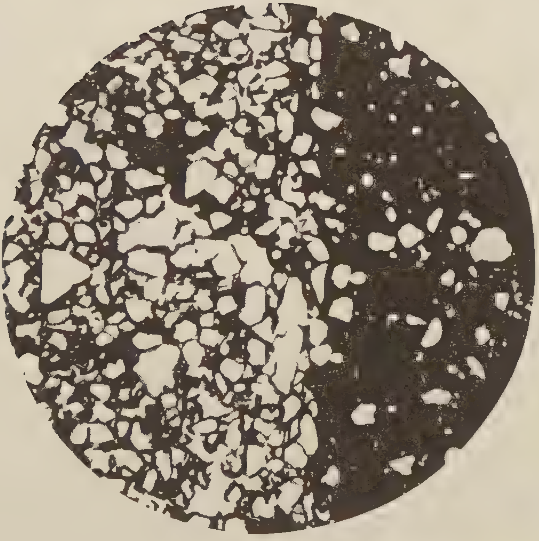

FIG 2. × 30.

ROCKS FROM THE LOWER AMAZON.

The dark part is the iron cement. The clear parts are quartz grains.

The latter is better exposed on the east side of the island where it was examined by Professor Hartt, who made the following observations :—

'The red ferruginous grit . . . is the only member of the series which appears at Arary where it may be followed to the Fazenda Nacional not far distant from the centre of the island. And now I observed this rock extending westward to a point opposite the mouth of the Tocantins. It is probable that a facies so much elevated, which extends such a distance along the north coasts and separates the Mondongos from the River Amazon has an even structure.

'The part of the island built upon this series is separated from the mainland and forms the primitive island which then formed a crescent with the alluvium deposited by the river. These deposits constitute the western forest country, the low centre portion, and the Mondongos.'"

Thus it would seem that the grit stretched from the middle of the island to the mainland and formed a barrier across what is now the Rio Pará (Fig. 1). The Amazon, with its tributaries the Tocantins and other northward-flowing rivers, would enter the sea on the north side of the island, which at that time would be little more than half its present size. When the barrier extending between the island and the mainland had been broken through a considerable volume of water would be diverted from the Amazon proper and would flow through the new channel (the Rio Pará). Immediately this happened a considerable amount of deposition would begin to take place on the north side of the island forming the swampy Mondongos and the other somewhat drier land towards Cape Maguarý.

It is possible that this topographical alteration is of comparatively recent date, for the rock itself can hardly be of any great antiquity. Although considerable search was made no organic remains of obviously contemporary date were found. Derby (3) who appears to have examined this rock but gives no details suggests that the beds " are evidently . . . modern and belong to the end of the Tertiary Age or the Quaternary."

Sections made in the campo land north of the middle line of the island show nothing but clay alluvium to a considerable depth. At a place some 25 miles north-west of Soure a very deep water hole (about 20 feet) had to be dug to provide the cattle with water. Nothing but alluvium was encountered all the way down. At the same time it was impossible to see any indication of stratification because the cattle trampled the whole of the surface as digging proceeded.

Less ambitious sections made in the open campo were more productive of information and showed clearly that extensive flooding had occurred at various times.

A. The top layer is about 9 inches thick composed of clay. During the wet season it must undergo a fair amount of " puddling " by the feet of the horses and cattle which roam these plains. Beneath this layer there is a thinner band B.

B. Composed of similar clay but containing great quantities of charred wood, indicating the previous existence of forest conditions. This does not quite agree with the views of Hartt (2) who seemed to think that on the north side of the belt of grit there has been no forest because of the youth of the deposits.

C. Below this old forest layer the succeeding 2 feet is composed of very light grey clay which contains patches almost white. This layer rests on a semi-liquid floor of unknown depth composed of slate-grey mud.

It is to the presence of this mud that a large part of the fauna of the island owes its continuity. At the end of the wet season when most of the swamps begin to dry up many fish, crabs, and possibly molluscs, burrow down into it and there remain until surface conditions become more favourable.

Shallow wells all over the north-east part of the island would seem to indicate that the land is still little more than a thin crust spread over a mudbank. But that the island is sinking there can be little doubt. From Soure to Cape Maguarý and westwards there are to be found the stumps of trees still standing quite a considerable distance out to sea or in the river. At Dunas I was shown where the ranch house had stood some ten years ago. The spot was considerably below high-water mark. Whether this sinking of the land is general throughout the lower Amazon region or whether it is a local phenomenon due to the settling down directly associated with the drying out of the mud beneath the island it is impossible to say.

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The Term "Crinanite".

By Frederick Walker, M.A., D.Sc.

Origin of the Term.

THE name crinanite was given in 1911 by Sir John Flett to a suite of N.W. analcite-dolerite dykes occurring in a fairly extensive district in Argyllshire of which Loch Crinan is the centre. A description of the type is accompanied by an analysis and a photomicrograph of a characteristic example from the island of Jura.[1] Writing a few months later of similar dykes in Colonsay, the same author gives a concise definition of the type—" The crinanites, then, are dark coloured, fine-grained, basic rocks consisting mainly of olivine, augite, and plagioclase felspar, with a considerable amount of analcite and zeolites." A detailed description follows, in which the very perfect ophitic structure of the rocks is emphasized, and another excellent photomicrograph is shown of an example from Colonsay.[1] In his original description Sir John Flett states that the crinanites "present some analogies to the teschenites in mineral composition; from the latter they are distinguished by their finer grain, their perfect ophitic structure, the scarcity of hornblende and biotite, and their occurrence as thin vertical parallel dykes".

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[1] " The Geology of Knapdale, Jura, and N. Kintyre," *Mem. Geol. Surv.*, 1911, 116, plate 5, fig. v.

The rocks in question form a very distinctive type for which a new name was certainly justified, but no micrometric measurements of the type example were given, with the result that the term crinanite has since been applied to rocks of widely differing mineral composition and grain. In this article the subsequent history of the term is outlined and the existing data amplified by means of new chemical and micrometric analyses.

Subsequent History of the Term.

In 1913 a short article by Dr. G. W. Tyrrell on the petrography of Arran was published in this Magazine.[2] Dr. Tyrrell then used the term crinanite for the coarse doleritic rocks of the Dippin and Kingscross sills. The rock of the Dippin sill had previously been described by Dr. A. Harker under the name teschenite,[3] but Dr. Tyrrell pointed out that both teschenitic and crinanitic types occur in this intrusion, the former being distinctly richer in zeolites. He stated further that the Kingscross sill is poorer in analcite than that of Dippin, besides being finer in grain and thus resembling more closely the type crinanite of Jura.

Since that date the term has been used in many of the Geological Survey memoirs, and has also appeared frequently in British petrographic literature. Only a few of the more important references will now be considered.

Professor A. Holmes in his invaluable book *The Nomenclature of Petrology* refers to the crinanites as "a variety of olivine-analcite-dolerite, containing purple augite and characterized by well-developed ophitic structure". This definition does not take into account the grain of the rock but otherwise agrees well with the original description of Sir John Flett.[4]

Three years later, in 1923, two papers dealing with this subject appeared in the GEOLOGICAL MAGAZINE. The first of these was by the present author,[1] and the second by Dr. Tyrrell.[2] The author suggested that only rocks in which analcite was present in sufficient quantity to cause analcitization of the felspar should be called teschenite. This definitely excludes the type crinanite of Jura in which the zeolite has only penetrated along the cracks of the felspar without causing appreciable replacement, but takes in the sills of Dippin and Kingscross. Dr. Tyrrell, on the other hand, extended the term crinanite, and grouped under the name "crinanite series" such rocks as the essexites of Crawfordjohn and Carskeoch and theralites of Ochiltree, etc. Kylite and peridotite were considered to be the mafic differentiates of the series, while differentiation towards the felsic pole produced analcite-syenite. The teschenite series was thought to be richer in analcite and poorer in potash felspar than the crinanite series, and to give picrite and bekinkinite as mafic differentiates, the corresponding felsic differentiate being lugarite. Dr. Tyrrell also suggested that the limited chemical evidence available showed the Tertiary crinanites to be poorer in potash than those of late Palaeozoic age. He thus embraced in his crinanite series rocks in the Central Valley of Scotland of Carboniferous and Permian age which had previously been regarded as normal ophitic olivine-dolerites or analcite olivine-dolerites, e.g. the rock of Drumcarrow Hill in Fife.

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[1] "The Geology of Colonsay and Oronsay," *Mem. Geol. Surv.*, 1911, 42, plate 6, fig. iv.

[2] G. W. Tyrrell, GEOL. MAG., 1913, 308.

[3] "The Geology of N. Arran," *Mem. Geol. Surv.*, 1903, 112.

[4] A. Holmes, *The Nomenclature of Petrology*, 1920, 71.

The data on which this interesting grouping was made proved, however, to be misleading, for in 1926 the author was able to show that the typical non-ophitic augite-teschenite of Charlestown, Fife, contained contemporaneous segregation veins of analcite-syenite.[3] Since this date further exceptions have been noted, and in the Arran Memoir Dr. Tyrrell would appear to have abandoned the classification, since he states again that both crinanite and teschenite occur in the Dippin sill.[4]

In 1925 Dr. A. Scott applied the name crinanite to the well-known dyke of Butterton in Staffordshire and to certain associated intrusions.[5] This use of the term is, however, not in accordance with the original definition, for the Butterton rock is porphyritic and non-ophitic. It had previously been described as nepheline-basanite, which is in every way a more suitable name.

Three years later, in his very complete description of the Howford Bridge sill in Ayrshire, Dr. Tyrrell referred to the mafic phase of that intrusion as crinanite, and gave a chemical analysis of the type.[6] Finding micrometric analysis of the rock impracticable, he derived the approximate mode of the crinanite by observations of thin sections checked by the norm of the chemical analysis. This appears to be the first quantitative record of the mineral content of a crinanite. The sill is probably of Permian age, and is intruded into lavas underlying red sandstones of that System.

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[1] F. Walker, Geol. Mag., LX, 1923, 242.
[2] G. W. Tyrrell, ibid., 249.
[3] F. Walker, Geol. Mag., LXIII, 1926, 347.
[4] G. W. Tyrrell, "The Geology of Arran," *Mem. Geol. Surv.*, 1928, 119.
[5] A. Scott, "The Geology of Stoke-upon-Trent," *Mem. Geol. Surv.*, 1928, 94, plate ii.
[6] G. W. Tyrrell, *Quart. Journ. Geol. Soc.*, lxxxiv, 1928, 540.

In recent years numerous rocks from the Outer and Inner Hebrides have been described as crinanites, and these show in many cases very strong resemblances to the type example of Jura. Micrometric and chemical analyses of several of these rocks appear below.

The term crinanite has also been applied to rocks outside Britain. In 1927 Messrs. W. Campbell Smith and L. J. Chubb described by that name a rock from the Austral Islands which they found to resemble very closely the facies of the Dippin Sill which is relatively poor in analcite. Fibrous zeolites were, however, absent from the foreign rock.[1]

All the available analyses of rocks which have been described as crinanite are tabulated on pp. 126–7 together with one fresh analysis of a Fifeshire rock of crinanitic affinities and almost certainly of Carboniferous age. These analyses are also expressed as Niggli values for greater ease of comparison. A series of micrometric analyses follows, all of these—with the exception of Howford Bridge—having been made by the author with the aid of the Shand micrometer.

Discussion of Chemical and Micrometric Analyses.

Examination of the above analyses brings out two points very clearly—first, that the type crinanite of Jura is more mafic than any other of the analysed examples and, second, that the proportion of zeolites which it contains is distinctly small. An interesting comparison may be made between the various chemical analyses of Tertiary crinanites and the average plateau-basalt magma-type (B) as calculated by Dr. Tyrrell. The two Staffordshire rocks should, however, be excluded, since their affinities lie with the nepheline-basanites rather than with the crinanites.

Analyses (3) and (5) show fairly close agreement with (B), but the others are more salic, except in the case of (1) which is more femic. The high percentage of magnesia in the type rock is outstanding, and is not matched in any of the other analyses.

It seems probable that all the crinanites under comparison are slight variants of the plateau-basalt magma-type, and the differences in composition might well be produced by crystallization differentiation possibly aided by an upward migration of volatile constituents. The rocks from the Shiant Isles (10) and the Loch Mealt sill in the north of Skye (8) were collected from portions of their respective intrusions which had been rendered relatively poor in olivine by demonstrable gravitational settling of that constituent, and both,

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[1] W. Campbell Smith and L. J. Chubb, *Quart. Journ. Geol. Soc.*, lxxxiii, 1927, 322.

TABLE I.

Analyses of Crinanites, etc.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(A)	(B)	(C)
SiO_2	43·94	43·95	44·21	44·15	44·68	44·69	45·09	47·51	47·80	47·83	45·4	45·8	46·2
Al_2O_3	14·03	17·60	16·38	14·60	16·37	14·17	9·90	17·28	14·54	15·31	16·1	15·0	13·7
Fe_2O_3	1·95	1·43	5·26	2·29	4·31	3·35	5·73	3·56	1·40	1·15	2·9	3·8	2·1
FeO	11·65	11·89	7·80	9·19	8·11	10·86	13·51	5·77	9·60	9·22	9·1	9·5	9·2
MgO	10·46	6·95	6·78	12·03	6·59	6·41	10·91	5·98	8·75	6·60	7·2	8·2	9·6
CaO	8·99	8·54	8·65	9·42	8·70	10·28	6·55	11·47	9·20	12·38	9·4	9·4	9·8
Na_2O	2·68	3·66	2·97	3·11	3·28	3·64	1·37	2·60	2·36	2·53	3·1	2·5	2·6
K_2O	0·33	0·35	0·47	1·55	0·21	2·01	1·55	0·79	0·85	0·40	0·4	0·5	1·4
H_2O+	2·31	0·82	1·77	1·12	1·69	2·53	1·50	1·40	2·00	1·28	1·5	1·8	1·6
H_2O-	0·85	0·94	2·35	0·30	2·99	1·05	0·38	1·30	0·90	0·28	1·4	0·9	0·4
TiO_2	2·45	3·42	2·58	1·56	2·51	0·46	2·59	1·80	1·90	2·86	2·6	2·4	2·4
P_2O_5	0·20	0·11	0·32	0·18	0·15	0·45	0·20	0·12	0·22	0·16	0·2	0·2	0·5
MnO	0·32	0·10	0·21	0·21	0·32	0·31	0·20	0·13	0·30	0·36	0·2	0·3	0·2
CO_2	0·16	nt.fd.	0·29	0·19	0·06	nt.fd.	0·95	—	nil	0·05	0·1	—	0·2
Etc.	0·10	—	0·16	—	0·07	—	—	—	—	0·03	0·1	0·3	—
	100·42	99·76	99·90	99·90	100·04	100·21	100·43	99·71	99·82	100·44	99·7	100·6	99·9

Niggli Values.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
al	17·2	23·0	23·7	19·0	22·6	18·3	12·6	24·3	19·5	20·6
fm	56·7	47·7	46·1	60·7	47·4	47·0	67·8	39·3	51·4	42·9
c	20·2	21·0	22·7	11·6	22·0	24·3	14·8	29·2	22·6	30·4
alk	5·9	8·3	7·5	8·7	7·8	10·4	4·8	7·2	6·5	6·1
k	0·06	0·05	0·08	0·24	0·04	0·26	0·42	0·16	0·19	0·09
mg	0·57	0·49	0·54	0·66	0·49	0·45	0·51	0·54	0·58	0·53
Qz	— 32	— 35	— 22	— 38	— 26	— 42	— 24	— 16	— 15	— 14

(1) Crinanite dyke, Slac nan Sgarbh, one mile north of Inver Lodge, Jura, Argyllshire. Quoted from "The Geology of Knapdale, Jura, and N. Kintyre," *Mem. Geol. Surv.*, 1911, 118. Analyst, E. G. Radley.

(2) Crinanite dyke, shore near Schoolhouse, Whiting Bay, Arran. Quoted from "The Geology of Arran," *Mem. Geol. Surv.*, 1928, 121. Analyst, W. H. Herdsman.

(3) Crinanite dyke, cave north of Mermaid's Hole, Lundy Island. Quoted from "Summary of Progress for 1915," *Mem. Geol. Surv.*, 1916, 77. Analyst, F. R. Ennos.

(4) Nepheline basanite (crinanite), Hanchurch Woods, Staffordshire. Quoted from "The Geology of Stoke-upon-Trent," *Mem. Geol. Surv.*, 1925, 97. Analyst, A. Scott.

(5) Crinanite sill, shore near Clauchlands Point, Arran. Quoted from "The Geology of Arran," *Mem. Geol. Surv.*, 1928, p. 121. Analyst, E. G. Radley.

(6) Crinanite, Howford Bridge, Mauchline, Ayrshire. Quoted from G. W. Tyrrell, GEOL. MAG., LX, 1923, 254. Analyst, A. Scott.

(7) Basic crinanite, Seabridge Borehole (535 feet), Newcastle-under-Lyme. Quoted from "The Geology of Stoke-upon-Trent," *Mem. Geol. Surv.*, 1925, 98. Analyst, A. Scott.

(8) Olivine-dolerite (crinanite), 80 feet above shore below L. Mealt, Trotternish, Skye. Quoted from F. Walker, *Trans. Roy. Soc. Edin.*, lvii, 1932, 254. Analyst, N. Sahlbom.

(9) Olivine-dolerite, Gathercauld Craigs, Fife. New analysis. Analyst, F. Herdsman.

(10) Crinanite, south face of Garbh Eilean, Shiant Isles. Quoted from F. Walker, *Quart. Journ. Geol. Soc.*, lxxxvi, 1930, 371. Analyst, E. G. Radley.

(A) Average of analyses, (1), (2), (3), (5), (8), and (10).

(B) Average plateau-basalt magma-type. Quoted from "The Geology of Arran," *Mem. Geol. Surv.*, 1928, 121.

(C) Average of three analyses of basalt of Dalmeny type taken from "The Geology of N. Ayrshire," *Mem. Geol. Surv.*, 1930, 100.

TABLE II.

Mineral percentage by volume, and grain of rocks.

	Olivine	Augite	Plagioclase	Iron Ore	Zeolites	Average length of Plagioclase laths
Jura (1) . .	18·7	18·9	52·2	7·2	3·0	mm. 0·5
Dyke I. of Mingulay	19·5	17·1	57·3	4·9	1·2	0·5
Clauchlands Pt. (5)	13·4	15·2	59·0	5·3	7·1	1·0
Dippin Sill (typical)	14·1	16·7	51·4	4·5	13·3	1·2
Shiant Isles (10) .	10	20	66	3	1	0·5
Dyke Fladdachuain [1]	12·5	19·0	50·5	5·0	13·0 [2]	0·8
L. Mealt (8) . .	7·3	14·3	73·7	3·4	1·3	0·8
Sill or lava West Gordon, Roxburgh	13·7	15·2	65·5	5·0	0·6	0·5
Gathercauld Craigs (9) . . .	19·0	15·0	61·5	3·2	1·3	0·3
Howford Bridge (6)	14	28	51	2	1	—

therefore, are more salic than (B). Doubtless olivine settled in the magma basin which produced the type crinanite dyke of Jura, the intrusion being drawn off from the relatively basic layer thus formed. Analysis (2) is somewhat exceptional, a high iron content being combined with surprisingly low magnesia.

The average composition of the Tertiary crinanites (A) agrees well with that of the plateau-basalts, the only noteworthy difference being the slightly higher alkali percentage of (A), and this is in favour of the foregoing hypothesis.

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[1] F. Walker, "The Dolerite Isles of the N. Minch," *Trans. Roy. Soc. Edin.*, lvii, 1931, 759.

[2] Includes a considerable proportion of indeterminable mesostasis.

Turning to the two Palaeozoic crinanites, it would appear that the chemical analysis of the Howford Bridge rock is of teschenitic character rather than crinanitic, being particularly rich in potash, and this is confirmed by the mineral composition of the rock in which the high percentage of alkali felspar should be noted. The Gathercauld rock, which has been described in detail by Mr. D. Balsillie,[1] is, however, much closer to the Tertiary crinanites both in chemical and in mineralogical composition, and in texture. It also shows a distinct chemical resemblance to the Dalmeny type of olivine-basalt (C). This type of basalt is exceedingly widespread in the British Carboniferous, and may possibly be regarded as the parent magma of that period of igneous activity. Certainly the available analyses show practically no variation.

The micrometric analyses show that the Jura type is not unique in its basic character, for it is closely matched by a dyke from Mingulay (Outer Hebrides) collected by Professor T. J. Jehu and Dr. R. M. Craig.[2] All the other examples are a good deal poorer in dark minerals than the type rock. The Palaeozoic rock of W. Gordon, however, bears a very striking textural resemblance to the Jura and Mingulay dykes, and the optical properties of the constituent minerals seem to be identical in all three cases.

A noteworthy feature of the Arran rocks is their high zeolitic content. The slices measured are stated by Dr. Tyrrell to represent the facies of the intrusions relatively poor in analcite (slide No. 24,456 from the Clauchlands sill, i.e. the analysed rock, and 6,361, 6,884, from the Dippin sill), and the zeolitic content of the teschenitic facies is distinctly higher.

To sum up, it may be said that very few of the rocks hitherto described as crinanite bear any close chemical or mineralogical resemblance to the type example from Jura. In most cases the texture is similar but the coarseness of grain shows a good deal of variation. Sir John Flett's original definition refers to the crinanites as " fine-grained . . . rocks ", and this cannot be said of many specimens examined by the author.

The time would appear to have arrived for a reconsideration of the exact significance of the term crinanite. It is not within the scope of this contribution to make any recommendation as to the use of the term, but it is hoped that the above data will prove of service if the matter is taken up by British petrographers.

Acknowledgments.

The author is greatly indebted to Dr. H. H. Thomas for the loan of the survey slices of the Jura, Dippin, and Clauchlands rocks, and to Professor T. J. Jehu and Dr. R. M. Craig for the gift of a specimen of the Mingulay crinanite.

[1] Dr. Balsillie, Geol. Mag., LXIX, 1922, 444.

[2] T. J. Jehu and R. M. Craig, *Trans. Roy. Soc. Edin.*, liii, 1923, 437.

REVIEWS.

History of the Theory of Ore Deposits, with a Chapter on the Rise of Petrology. By Thomas Crook. pp. 163. London: Thomas Murby & Co., London, 1933. Price 10*s.* 6*d.*

THE author, in his summary (p. 12) concludes that, " we may therefore reasonably infer that the modern igneous theory of metalliferous veins is not in harmony with the main facts to be accounted for, and that future investigation is likely to diminish the prestige of this theory." In reaching this conclusion he leads his readers interestingly, if at times a little blindly for one who aspires to be a guide, through the views, held from the time of Thales to the present day, on the origin of ore deposits. In reading this survey, a mature student of the subject cannot but feel that the author's acquaintance with it is academic rather than practical, that the weights given to the opinions of different workers who have lived within the author's own lifetime, have been arrived at much more from perusal of " the literature " than from participation in discussions or controversies or a personal acquaintance with the workers themselves, or the ore deposits they dealt with.

In spite of this disability (and we are all the victims of our experience) the author has compressed into the small compass of his book, the most readable and readily-accessible history of the subject. At times there is an obscurity, however, in appreciation of the problems involved. For example, on p. 19, in emphasizing the importance of geodynamics, he apparently forgets that line of investigation only elucidates one factor in origin of ore deposits, i.e. geological structure, leaving another and equally important factor, mineralization, which can only be satisfactorily investigated as to its genesis by " chemistry, physics, and physical chemistry ". It is essential for the proper examination and study of any ore deposit that those two factors should be clearly distinguished. Consideration for geodynamics is very desirable, but that subject is only competent to account for geological structure, and to claim more for it is to misrepresent the case. Regarding the mineralization factor, always involved in an ore deposit, of the independent variables—temperature, pressure, concentration—of all of which mineralization is a function, there is a much higher degree of probability that the temperatures, pressures, and concentrations which it is necessary to assume as having been existent in the formation of many ore-deposits, were associated with a magmatic (hypogene) rather than an exogenic (supergene) mode of genesis. The chief reason why exogenic processes and vadose solutions have not been assigned a wider role than they have by workers on the genesis of ore deposits, is that no acceptable mechanism based on sound " chemistry, physics and physical chemistry ", can be found for so doing. By what rational extension of the exogenetic views of the author of the book, for instance, could they be stretched far enough to account reasonably for formation of the argentiferous cobalt-nickel veins of Cobalt, for the nickel deposits of Sudbury, or for the auriferous quartz veins of Porcupine and Kirkland Lake, all in Ontario ?

The author (p. 104) regards as ". . . a rather remarkable fact that side by side with this growing popularity of the igneous exudation theory as advocated by Kemp, Lindgren, and others, there grew up, in the United States, a recognition of the importance of the process of secondary enrichment as explaining the richness of many ore deposits, more especially the copper ore deposits of Montana, Arizona, and other parts of the United States." Now, surely, though the author does not so ascribe it, such recognition is really a tribute to the broad-mindedness and scientific impartiality of those "theorists" (p. 105), amongst whom he mentions Kemp and Lindgren (the latter with his thirty years of active association with the United States Geological Survey, too !), who thus impartially assigned a magmatic or an exogenetic origin when they considered such, separately, applied. His allusion to that reaction in 1893 from the views of Sandberger, to those favouring a magmatic origin, as being "engineered (p. 17) by Posepny", reads harshly in view of that distinguished worker's lifetime of disinterested devotion to the *actual study* of the ore deposits of his native land. In these two instances the author rather forfeits claim to that impartiality on his own part that is so desirable in one who aspires to be an historian.

The weight the author attaches to the opinions he reviews is, too, somewhat peculiar, for, after devoting two and a quarter pages to the views of W. Kemp, a bare two pages to those of W. Lindgren, he allows five pages to W. H. Goodchild, five to Morrow Campbell, and five to J. E. Spurr, or a total of fifteen pages to three writers whose views have in no way seriously influenced the trend of economic geological doctrine. Though it is true that in so doing the author wishes to expose extreme and strained views favouring magmatic origin of ore deposits, he might, in all fairness, have mentioned the extremely cool reception given by economic geologists generally to the latest attempt (to the tune of 185 pages of specious, special pleading) to ascribe a magmatic origin for the gold in the auriferous conglomerate (banket) of the Witwatersrand ! The author misses the point, too, that the tendency, admittedly existent of recent years, to use magmatic origin as a sort of shibboleth (against which practice the author inveighs), has been displayed much more by economic geological writers of papers descriptive of particular ore-deposits and by mining engineers than by *authorities* on economic geology. In the same way, extreme claims for application of a magmatic theory of origin of ore deposits generally, have met with but scant support from reputable economic geologists and, as indicative of their views, W. Lindgren has placed himself on record as holding that ". . . certain limitations and a certain conservatism are imposed upon him who would write a textbook. A logical and consistent presentation requires that the author should not be carried away by extreme views and hypotheses. He must appreciate that some of that which is fashionable is not necessarily true and he must try to steer an impartial course in the troubled sea of conflicting opinions ". Again, the author, out of touch as he apparently has been with economic geological tendencies in U.S.A., is not aware that the views of J. E. Spurr met with a much greater degree of acceptance from mining engineers than they did from trained economic geologists who were the first to take exception to the ludicrously extreme application of those views that were attempted. For ready acceptance of new and extreme views it is to the mining engineer that must be rightly ascribed that marked preference for " a simple and direct hypothesis, the entertainment of which frees him from the irksomeness involved in a cautious application of the principles of science ", including economic geology, which the author records and, inferentially, so justly condemns.

In the section of the book dealing with " The Rise of Petrology " the author's views on the well-founded claim of ore deposits to be included in a full treatment of rocks and, consequently, in petrology, will meet with ready acceptance by economic geologists generally, if not by petrologists. There is no getting away from the fact that an ore deposit is a rock and the omission of a treatment of ore deposits by petrologists leaves petrology as a badly-emasculated branch of science, and the neglect by most petrographers to deal with rock alteration still further widens the gap between present-day petrology and a complete study of rocks, including ore deposits. The author interestingly traces out how the separation began, but in addition to the causes given by him it seems to this reviewer that contributory ones have been, partly, the non-amenability of ores to microscopic examination by transmitted light and partly also, in Great Britain at any rate, to that strange aloofness of academic geologists, beginning with Lyell, from anything that savours of applied or economic geology. The author's call for a reconstituted and wider petrology, that will include ore deposits and thus cover all rocks in its scope, is distinctly opportune and he might well have mentioned the efforts in the same direction of P. Niggli, who has insisted that " The problems encountered in the study of ore deposits are parts of the wider problems arising in connection with the study of igneous rocks."

The author has succeeded in presenting his subject concisely and interestingly, and, with its clear type, general get-up, and freedom from typographical errors, his book should be on the shelves of every student of economic geology and in the library of every geological department. The advanced student will know how to accept those portions that have been here criticized and the undergraduate should have the pitfalls pointed out to him.

H. C. Boydell.

THE GEOLOGY OF THE COUNTRY AROUND HOLMFIRTH AND GLOSSOP: Explanation of Sheet 86 N.S. By C. E. N. BROMEHEAD, W. EDWARDS, D. A. WRAY, and J. V. STEPHENS, with Notes by G. V. WILSON and W. LLOYD. Mem. Geol. Survey. pp. viii + 209, with pls. 5 and figs. 18. 1933. Price 4*s*.

SHEET 86 of the New Series one-inch map includes portions of both the Yorkshire and Lancashire coalfields and a wide area of moorland which lies between. Its rocks are not of great economic value, but the re-mapping has provided much information of use in the unravelling of the stratigraphy and structure of the coalfields on its flanks, and the district is of interest to dwellers in the neighbouring industrial areas as catchment ground for waterworks and for its scenery.

The opening chapter of the memoir discusses many subjects, from local place-names to the general succession of the rocks, and is followed by an account of the Millstone Grits whose outcrop occupies a greater area than that of any other part of the succession. The Millstone Grits are little different from their equivalents to the north and north-west and the persistence of their major sandy horizons has now been verified by the successful tracing of the goniatite bands in the interbedded shales. In no part of the series is the importance of these fossil bands greater than among the " Middle Grits ", which have been reduced to order by their aid. A correlation of these grits has now been made over wide areas, and we now know with certainty that the Rivelin Grit of Sheffield, the Midgeley Grit of Halifax, and the Gorpley Grit of East Lancashire are on the same horizon. An interesting point which emerges here is the predominance of the Huddersfield White Rock to the north of Penistone where its escarpments are stronger than those of the equivalents of the Rivelin Grit, a reversal of the conditions prevailing further south.

The palaeontology of the Upper Carboniferous rocks is well set forth, and by tabulations and diagrams a graphic account is presented of the stratigraphical relationships of the goniatite bands to the grits of the Millstone Grit series and of the non-marine lamellibranchs to the coal seams and " rocks " within the Coal Measures. Shells attributed to the genus *Carbonicola* are recorded from the shales which rest upon the Huddersfield White Rock.

The subdivisions of the Upper Carboniferous rocks are, for convenience, drawn at traditional horizons, but it is pointed out that more logical divisions might be made at the top of the " Middle Grits ", where the fauna characterized by *Reticuloceras* gives place to that with *Gastrioceras*, and again at the Better Bed Coal or at its equivalent horizon of the top of the Greenmoor Rock, which marks the dividing line between the zones of *Carbonicola lenisulcata* and *C. ovalis*.

The Lower Coal Measures cover about a quarter of the area of the sheet, mainly in the north-east. Two points of interest about them are the southward failure of the Better Bed Coal and the intricate variations of the Whinmoor group of coals. The lowest portion of the Middle Coal Measures is exposed over about five square miles in the north-east corner of the map. It is interesting to notice that the re-survey has confirmed the correlation of coal seams originally put forward by Green.

The variations, more particularly the thinnings, of the coals are found to be associated with a general diminution of thickness of both Millstone Grits and Lower Coal Measures towards an east-west line across the north-eastern part of the map. This was a persistent line of tectonic disturbance and was active during the deposition of the Upper Carboniferous rocks from Millstone Grit times until most of the Middle Coal Measures had been laid down. Farther to the east, where the higher coals are affected, the line has long been accepted as the natural boundary between the coal trade districts of West and South Yorkshire. In this memoir it is designated the Holme Disturbance.

The dominating structures of the district are the North and South Pennine and Mossley anticlines along its western edge, and the Alport Dome, the northern part of the Peak of Derbyshire, in the south. The westward dips from the crest of the Pennine and Mossley anticlines are steep, those of the Alport Dome are gentle, while over the remainder of the area the measures are inclined at small angles towards the north-east. The faults of the western anticlinal region trend north and south and hade steeply, those in the remainder of the district are either north-west or north-east, these latter tending to swing round to a direction nearly east and west as they curve round the north of the Derbyshire Dome.

A descriptive chapter on economic geology contains much information about water supply, the characteristics of the local coals, fire clays, and other mineral products.

The memoir is attractively written and eminently readable and should arouse the interest alike of pure and economic geologists as of those who wish to acquire a better appreciation of the scenery of the countryside. It is one on which the officers of the York unit are to be congratulated.

W. H. W.

TREATISE ON SEDIMENTATION. By W. H. TWENHOFEL and Collaborators. 2nd edition. pp. 926 with figs. 121. London: Ballière, Tindall, and Cox, 1932.

THE preparation of the second edition of this well-known book has been in hand for no less than seven years, the first edition having met with immediate success and being soon out of print. This in itself affords ready testimony to its value. The recent literature of the subject in all the more intelligible languages has been thoroughly ransacked in the meanwhile in order to bring the book up to date and the total number of references given is enormous, amounting in some chapters to many hundreds. It is improbable that anything of first-class importance has escaped notice, though perhaps a little more space might have been devoted to British work on the heavy mineral constituents of sands and sandstones, which is passed over somewhat lightly.

In consideration of the great number of different matters involved in the subject of sedimentary petrology it would be invidious to pick out any special points for detailed discussion or criticism: in the case of a work so wide in scope it is only possible to express appreciation of the enormous amount of labour devoted by the contributors to the work, for which, as is expressly stated, they receive no payment or even royalties on sales. It is a source of great gratification to geologists of broad, general outlook on their science that this particular branch of it, till lately much neglected, should receive such generous recognition in America. The petrology of the sediments has hitherto tended to be somewhat overshadowed by the great amount of attention paid to the igneous and metamorphic rocks, whose problems are perhaps at first sight more spectacular, though probably not in reality of greater importance, and even this attitude has been somewhat vitiated by the resolute determination of many leading petrologists to ignore the study of the ore-deposits of magmatic origin, which actually present some of the most interesting problems of petrogenesis. However, we may hope that this academic attitude is now, or shortly will be, a thing of the past, and that the whole field of petrology will soon receive adequate recognition: towards this highly desirable end the book under review is a contribution of the greatest value.

THE SUCCESSION OF FOSSIL PLANTS IN THE MILLSTONE GRIT AND THE LOWER PORTION OF THE COAL MEASURES OF THE SOUTH WALES COALFIELD (NEAR SWANSEA) AND A COMPARISON WITH THAT OF OTHER AREAS. By EMILY DIX, D.Sc., F.G.S. *Palaeontographica*, Bd. lxxviii, Abt B, pp. 158–202, pls. xx, xxi.

THE Upper Carboniferous rocks have already been zoned by means of goniatites and non-marine lamellibranchs. Dr. Dix is to be congratulated on having attempted a further sub-division of the rather large plant divisions on similar lines. Having examined the floras of the Millstone Grit and the lower portion of the Coal Measures in three areas in South Wales—namely, Abercrave, N. Gower, and Pembrokeshire—she proposes to group the strata concerned into four floral divisions based on certain Continental zones.

With regard to the lowest zone, that of *Lyginopteris stangeri*, recognized in the Abercrave district (the Penwyllt Plant Beds), Dr. Dix has not found the zonal plants in Gower (p. 168), while in Pembrokeshire "although the boundaries between successive zones cannot at present be fixed with any precision . . . the flora from the radiolarian cherts, although scanty, probably belongs to the zone" (p. 169). These beds at Abercrave appear to be "not above the goniatite zone H" (p. 163).

The succeeding zone, that of *Pecopteris aspera*, has not been recognized by its flora at Abercrave, where it is regarded as "roughly comparable to the goniatite zone R" (p. 164). In North Gower no plants were found in this zone (p. 168), while in the corresponding division in Pembrokeshire the plants (unspecified) are described as "rare" (p. 169).

The zone of *Neuropteris schlehani* (equivalent to part of the goniatite zone G and the lamellibranch zones of *A. lenisulcata* and *C. ovalis*) is represented in Abercrave (p. 164) and in Pembrokeshire (p. 170), but the zonal fossils are not recorded with certainty from North Gower (p. 168). There seems to be great difficulty in drawing a line between this and the succeeding zone, but on such evidence as is available the line given by Dr. Dix appears to be unduly high in the sequence.

The zone of *Alethopteris lonchitica* occurs round Abercrave (p. 167), is probably represented in Pembrokeshire (p. 170), but has not been recognized in North Gower (p. 168).

These observations may be summarized as follows:—

TYPE AREA (S. WALES).

Zone of	Abercrave	N. Gower	Pembrokeshire
Alethopteris lonchitica and *Neuropteris heterophylla*	Recognized	Not recognized	Probably present
Neuropteris schlehani and *Lyginopteris hoeninghausi*	Recognized	Doubtful	Recognized
Pecopteris aspera . .	Not recognized by the flora		
Lyginopteris stangeri and *Alethopteris* cf. *parva* .	Recognized	Not recognized by the flora	Probably present

On the above basis Dr. Dix institutes comparisons with other areas. In the Culm Measures of north-west Devon the *Neuropteris schlehani* zone occurs around Bideford (pp. 172–3), while the plants found at Summer Hiscott are "possibly within the zone of *Alethopteris lonchitica*" (p. 174).

In Lancashire "plants characteristic of the zone of *Neuropteris schlehani* and *Lyginopteris hoeninghausi* occur in the goniatite zones of R and G". The zone R had previously been described as approximately equivalent to the lower plant zone, that of *Pecopteris aspera*. However, " much more work is necessary in this area before the limits of any plant zones can be fixed " (p. 175).

The Derbyshire and Yorkshire area has yielded very few plants from the lower portion of the Upper Carboniferous. Kidston recorded *Lyginopteris stangeri* from the Yoredale Beds, while Dr. Dix had identified the *N. schlehani* suite in the roof of the Kilburn Coal. In Northumberland and Durham the *N. schlehani* suite appears to range from the High Shilford Coal to the Busty Seam.

In Scotland *Lyginopteris stangeri* was recorded by Kidston from the lower third of the Millstone Grit and the Upper Limestone Group, E_2 of Bisat's classification, while the *Neuropteris schlehani* suite is recognized in the upper two-thirds of the Millstone Grit and the lower portion of the Coal Measures, though Dr. Dix has not been able to fix the lines between these divisions.

These comparisons may be summarized as follows :—

Zone of	N. Devon	N. Staffs	Lancs	Derby and Yorks	North'd and Durham
A. lonchitica	" Possibly present "			Present	Present
N. schlehani	Present		Present	Present	Present
P. aspera	Zone not recognized by its flora				
L. stangeri	Not recognized	Recognized	Not recognized	Recognized	Not recognized

There is no marked floral break between the Lower and the Upper Carboniferous in South Wales. In N. Staffordshire certain species which were regarded by Kidston as belonging to the Lower Carboniferous are observed by Dr. Dix to extend upwards into the zone H. It is to be noted, however, that the position assigned to the zone of *A. lenisulcata* in the table facing p. 166 does not accord with that in Yorkshire.

It will be evident, from the above, that, valuable as this work is, much remains to be done. Until a floral sequence has been worked out in considerable detail and that in several areas, the present writer considers it unwise to regard (as Dr. Dix is inclined to do) the zones based on goniatites as interchangeable in terms of plant zones.

The author concludes by repeating the suggestion that the terms Lanarkian and Yorkian should be superseded. The connotation of these terms has necessarily undergone modification in recent years. Nevertheless, no advantage would accrue from replacing them by the zones suggested above.

R. CROOKALL.

Die Orogentheorie. By L. Kober. 184 pp. with 50 text-figures. Berlin, Borntraeger, 1933.

In this book Dr. Kober sets forth his latest ideas on the structural history of the earth: this is a large subject and affords an embarrassing number of topics for comment. The treatment is necessarily very condensed, as there are only 175 pages of large-type text, and unfortunately for the reviewer the main thesis of the argument is almost impossible to explain without the figures. Dr. Kober's leading idea may perhaps be best summarized as lying in the contrast of " Kratogen " and " Orogen " as the two main types of structural unit, and for convenience these two words may well be adopted into English to express the contrast between stable blocks and labile regions respectively. The relation of geosynclines to orogenic uplifts is a commonplace of modern geology, well known to everybody, and the Kratogen is, of course, the opposite: the stable blocks that do not undergo folding. In the whole argument, it may be noted, the general contraction of the earth is always implied and often explicitly invoked, without comment, as an accepted fact. If this contraction is to be attributed to cooling, in the earliest stages of earth-history it is a self-evident proposition, but since the Cambrian, or even earlier, by no means so. At this stage of geology it may well be asked, is the earth cooling? is it cooler now than it was during the pre-Cambrian ice ages? Probably not, and yet since then there have been several phases of orogenesis, with a most obvious shortening of the crust. The explanation may perhaps be that while the temperature of the crust at and near the surface remains pretty constant, the layers a few miles down were hotter, the temperature gradient being steeper and subcrustal contraction more active in earlier times. The wide variations in temperature-gradient even now suggest that the earth is far from being in thermal equilibrium.

In this book very little is said as to geological history in pre-Cambrian time. It is nearly true to say that Dr. Kober starts off with the earth in its earliest Palaeozoic condition, and discusses it mainly on the basis of three episodes; the Caledonide, Variscide, and Alpide revolutions. These terms are used throughout in the chronological and not in the directional sense, and some uses of the terms may be rather a shock to British geologists, accustomed to associate them with trend-lines rather than with dates. In the whole of geological literature there is an unfortunate ambiguity on this point, which has done much to confuse the issue. The doctrine of posthumous movement receives scant recognition in this book, and the influence of the earlier N.W.–S.E. Huronian or Charnian trend-lines on the structure of Europe is ignored, even though the Saxonian disturbance is briefly discussed.

At frequent intervals throughout this book, and others, there are found references to the " Germanides ". In spite of much laborious reading the present reviewer has never been able to arrive at any clear conception of the meaning of this blessed word. Is it possibly the last refuge of theorists whose theories do not work?

Dr. Kober regards the Atlantic as a rather complicated geosyncline, compressed, as to the northern half, between the Russian and Canadian shields, with a band of Caledonides on their margins; then two rather narrow sunken blocks, with the central ridge as an Alpine orogen: farther south the sunken blocks are wider, but the general structure is the same. It may here be remarked that Dr. Kober will have nothing to do with Gondwanaland: in fact he definitely states his opinion that no such continent ever existed, and his interpretation of earth-history if carried to its logical conclusion seems to bar completely continental drift on any but the smallest scale. When dealing with the late-Carboniferous ice-age as manifested in Africa he places the South Pole some ten degrees south of the Cape of Good Hope, but this completely ignores the salient fact that the movement of the ice, beyond any cavil, was from the Transvaal southwards, that is, directly towards his supposed pole. The reviewer has himself studied on the spot the evidence for this.

With regard to the Pacific the main thesis is that the structure of this differs in no essential from that of the rest of the world. " Our analyses lead to the conviction, that the same structural plan prevails here that we have learnt to recognize in the continents " (p. 148). In other words the Pacific has essentially the same structure as the Atlantic: fold-zones extend far out, especially on the western side, as shown by the New Guinea–New Caledonia–New Zealand arc and others still more external, while the volcanic islands of Hawaii appear to play much the same part as the central ridge of the Atlantic.

Space will not allow of more than the baldest reference to the author's most interesting discussion of the Mediterranean geosynclinal and the linking of the Alpine chains, or of the ultimate structure of the Alps themselves: we can only say that he joins the Dinaric Alps, the southern Alps, the Apennines and the northern Atlas as one southward-moving unit, and that the northern Atlas is made to bend round as the Riff arc across the Straits of Gibraltar to the Betic Cordillera, Sardinia, and Corsica, to link up with the Alps of Provence, thus appearing to close the geosyncline at the western end. The evidence for this behaviour of the Riff arc seems to be founded on the author's own observations, as well as his elucidation of some regions further east.

This book will afford much food for thought, and the style is so clear that even readers with but a limited knowledge of German can rarely be in doubt as to the meaning. There is a very extensive bibliography, running to nine pages: in this we have only been able to find references to two English works, though a few American authors are cited.

R. H. R.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

25th January.

Professor C. E. Tilley exhibited specimens and sections of a new mineral hydrocalumite from Scawt Hill, County Antrim, Northern Ireland, and Mr. A. T. Dollar exhibited bent and twisted quartz crystals from Lundy Island, Devonshire.

Dr. James Phemister: Zoning in plagioclase feldspar. The paper describes various types of zoning in plagioclase feldspar in the calciferous sandstone basalt lavas in one district of Scotland. The zoning is classified as (*a*) normal, (*b*) simple reverse, (*c*) oscillatory. Simple reverse zoning is associated with other differences in the zones which point to important time intervals between the growth of the zones. Oscillatory zoning is classified as oscillatory-normal and oscillatory-reverse and attention is drawn to the occurrence of oscillatory-zoned crystals which show no general tendency towards either more calcic or more sodic plagioclase. Distinction is drawn between the main zones and the thin shells of alternately more and less calcic composition within the main zones. The alternating composition of the thin shells is possibly the result of lack of balance between rate of growth of the crystal and rate of diffusion from the surrounding magma. Recurrence of calcic plagioclase in the inner part of main zones is explained as the result of irruption of hot magma into the crystallizing liquid, probably consequent on eruption of lava at higher levels.

Professor H. H. Read: On zoned associations of antigorite, talc, actinolite, chlorite, and biotite in Unst, Shetland Islands. In an injection zone within the staurolite-kyanite-garnet-gneisses of western Unst occur spherical or ellipsoidal bodies, up to 20 ft. diameter, composed of an interior of antigorite, followed outwards by an orderly sequence of zones made up entirely of talc, of actinolite, of chlorite, and of biotite. It is considered that the zoned bodies result from the fragmentation of peridotite sills during the staurolite-kyanite-garnet metamorphism, followed by the entry of fluids into the masses during injection-metamorphism and the formation of the zonally-arranged layers. At the same time material displaced from the masses reacted with the country-rock to give the biotite zone. Transitions to the country-rock were mostly pared away during the later chloritoid- and chlorite-producing metamorphisms that have affected the staurolite-kyanite-garnet-gneisses.

Mr. M. H. Hey and Mr. F. A. Bannister: Studies on the zeolites. Part VII. Clinoptilolite, a silica-rich variety of heulandite. Rotation photographs of a single crystal from the original specimen of "clinoptilolite" (so-called "crystallized morderite" of L. V. Pirsson) show that it is a silica-rich variety of heulandite. The chemical composition and optical properties are in agreement with this interpretation. The mineral bears no relation to ptilolite.

Mr. B. Ramo Rao and Dr. A. Brammall: Notes on cordierite in the Dartmoor granite. Two groups of associated but as yet unrelated facts were recorded concerning the sector-twinned cordierite in the garnetiferous granite of Sweltor: (1) an aggregate of cordierite grains is separable into fractions varying in composition; in particular, the molecular ratio FeO/MgO varies from 0·37 to 1·28 in six intermediate fractions analysed, the ratio for the aggregate being 1·52. (2) all sectors are optically negative, but the value of 2V varies between 56° and 72°. Centrally paired sectors give the same 2V value, whereas adjacent sectors often give different values, the maximum difference observed being 12°.

CORRESPONDENCE.

MECHANISM OF EARTH MOVEMENTS.

Sir,—Mr. R. G. Lewis's paper "A Search for the Mechanism of Earth Movements" (Geological Magazine, November, 1933) has fairly astonished me. I will not discuss his hypotheses, as they are too vaguely put and have not been worked out well enough to allow any discussion. I may refer to the remarks of Mr. H. Jeffreys on the requirements of a theory in general (*The Earth*, Appendix C 4, p. 324). There are further, in this case, some special requirements to be satisfied. Whether the factor 1·7 and the equality of terrace intervals between different sites really exist must be proved by a thorough analysis with the calculation of probabilities. If then their existence is proved any explanation given must also explain these points, which is not done by Mr. Lewis's hypotheses. But his method of making use of the facts may be discussed. And here I have some serious objections:—

(1) In the case of the Dancala Depression, he omits two steps in his Fig. 5: the step at −20 to −30 and the one at −62 m. (See p. 501.)

(2) On p. 504 he says that "each successive deficiency is almost exactly three times the last". This is not true. But every two deficiencies are almost exactly three times the next two, which makes the relation more complicated than probable. But may we speak of a relation at all, when only five steps of the twelve found show this relation? And last of all the coincidence has been brought about by Mr. Lewis himself, by taking 1·79 for his factor. He could even have done better by taking 747·1 for the highest terrace and 1·1642 as a constant. Then all the terraces fit in with a departure from the theoretical curve of less than 5 per cent, excepting the terraces II–VI, which give deficiencies with a constant ratio of −1·4029, with only five terraces being eroded away and the one at −20 to −30 m. being neglected. [747·1; (−641·8); 551·2; −473·5; 406·7; −349·4; 300·1; −257·8; (221·4); (−190·2); 163·4; −140·4; (120·3); −103·6; (88·9); (−76·4); 65·6.] But then, of course, we can get as perfect a fit as we like by taking the constant as near to unity as is necessary.

(3) (Fig. 8, first period and Fig. 10). When we apply his theory to the case of the Oxford river terraces we would expect that the Old Wolvercote channel would have been cut more deeply than the sunken channel as, according to Fig. 10, there was more time. But even if we take a constant wavelength, the fall of the river would have been greater. So the maximum height for this channel would be 17 feet below present sea-level, the minimum being of course 58·5 feet below present sea-level. This is inconsistent with his Fig. 8. Moreover his two figures do not agree, as what is the Summertown–Radley channel in the first instance is taken for the Buried Channel in Fig. 10.

(4) The most astonishing thing, however, is that, when trying to account for the Bilbao profile (Fig. 1), which is inconsistent with his theory, he proves the Nive profile to be theoretically at fault, whereas the Nive profile is one of those on which his theory was based. In doing thus he weakens his own theory, leaving the Bilbao profile unaccounted for.

(5) When, moreover, he speaks of a rising of the land between the Pyrénées and Armorica towards the end of the beachforming period, he is quite wrong and in contrast with his own data. Let us make the same assumptions as he does, viz. (*a*) that of two terraces the higher is always the older; (*b*) that of each terrace the higher margin was formed earlier than the lower; (*c*) that the whole range of land, where the terraces occur, moved *en bloc*; (*d*) his theoretical heights for these terraces and the deficiencies resulting from them. We must bear in mind that the movement that we are in search of is the differential movement superposed on the oscillating movement. Now let us denote by a, c, e, g, i the movements of the land during the formation of the first (highest), 2nd, 3rd, 4th, and 5th terrace respectively; and by b, d, f, h the movements of the land between the formation of two terraces, and by j, the movement afterwards.

According to assumption (*b*), a, c, e, g, and i will be positive. According to assumption (*c*) each terrace margin will be found now at a height, which is expressed by the sum of all the movements occurring after its formation. We then find: $a = 0$; $b = -15$; $c = +15$; $d = -17$; $e = +17$; $f = -19$; $g = +8$; $h = -7$; $i = +2$; $j = -10$. If we reverse assumption (*b*)—the only supposition we may change without discarding the whole theory—we get: $a = 0$; $b = 0$; $c = -15$; $d = +15$; $e = -17$; $f = +6$; $g = -8$; $h = +3$; $i = -2$; $j = -8$. The result in both cases is an irregular movement with the general character of a subsidence.

(6) Perhaps I may be permitted to make some more positive remarks too. The fact still remains that, if we take Mr. Lewis's graphic method consistently, most of the profiles mentioned still show a convexity towards the X- and Y-axes. This again may be due to chance, as the number of profiles is rather small. Two factors, however, can be indicated that might tend to cause this

convexity. First, it may be more probable for higher terraces or beaches to be eroded away than for lower ones. Secondly, if a set of beaches little differing in height is raised to some altitude, they will more often than not be taken together as one beach, as might be indicated by the wide margins given for some of the raised beaches. Both factors will make the left side of the curve steeper than it would originally have been, resulting in giving the curve a tendency to convexity towards the X- and Y-axes.

H. J. MacGillavray.

Mineralogical Geological Institute,
Utrecht, Holland.

THE GLACIAL SUCCESSION ON THE NORTH COAST OF NORFOLK.

Sir,—By the publication of his paper (*Proc. Geol. Assoc.*, xliii, pt. 3, 1932, 241–271), Dr. Solomon has made another and a valuable contribution to our knowledge of the very complex problem of the glacial succession on the north-east coast of Norfolk. During the last fourteen years I have made very numerous visits to the area dealt with by Dr. Solomon and have carried out a close examination of most of the deposits with which he deals. The object of my excursions to the Norfolk coast has been the excavation and collection of flint implements, and I suppose I am one of those responsible for the finding of these specimens in situ in various beds, of which Dr. Solomon speaks. I fear, also, that I am to be numbered among the archæologists who have indulged, though I trust not, in my case, in an orgiastic manner in the correlating of certain types of implements with these deposits. However, having always proceeded with due care and caution along this difficult path, I am hopeful that my tentative efforts will not be included among those which are condemned by Dr. Solomon as "ill-informed". There is, of course, not much doubt that some of the correlations which have appeared in various publications are of small value. But the archæologists may perhaps be forgiven for this because, after all, if it had not been for their investigations, carried out quite frequently in the face of determined opposition by geologists, the latter to say the least would have experienced considerable difficulty in extricating themselves from the mono-glacial morass, and the slough of despond of the post-glacial age of man.

I hope my geological friends will forgive me for reminding them of this historical fact, which appears at times to be in grave danger of being overlooked and forgotten.

There are, however, many things for which archæologists should be thankful; and I trust I am duly appreciative of Dr. Solomon's statement that, while the implements I have found in the Stone Bed, near Cromer, are not "universally accepted", nevertheless "the bulk of archæological opinion is inclined to accept their authenticity ". Dr. Solomon states, further, that these flint implements should not be called " Chellian ", " for the dominant type is not the *coup de poing* but rather a roughly trimmed flake implement. . . ." Now, as to these claims, I would say first of all that, while I do not think that any flint implement should be called by such an unmeaning name as " Chellean ", I nevertheless consider that the specimens I have found in the Stone Bed mentioned are as much entitled to that term as are any others to which it is usually applied. For my experience has shown that the " dominant " type of artefact in the Stone Bed under discussion is a coarsely flaked, core hand-axe. And though there may be some room for argument as to whether " Chellean " is a fitting term to apply to a flint implement, the question as to what is the dominant type of artefact in the Stone Bed near Cromer is a matter which can be settled by excavation and observation.

Dr. Solomon claims that the *provenance* of the ochreous specimens found by me on the foreshore at Cromer and elsewhere is " doubtful ". There are, unfortunately, many doubtful things in archæology, and I suppose that even geology is not entirely exempt from them ; but, as to these ochreous flints, I can at least claim that I have been at considerable pains to make public in detail[1] my reasons for believing these specimens to have been derived from the Stone Bed. In this view I may, of course, be mistaken, but in any case it is a matter of much importance and I hope that Dr. Solomon will be able to tell us why he thinks the *provenance* I have claimed for the ochreous flints is doubtful and to what horizon he would himself relegate them. I am sincerely anxious to have this difficult matter elucidated, and shall welcome any scientific criticism he cares to make of my findings. I find myself unable to accept Professor Boswell's claim that the Chellian period " straddled two glacial episodes ", though I realize he is perfectly justified in making it, owing to the absurd manner in which archæologists apply the term Chellean to hand-axes of very different types and degrees of antiquity. In my opinion this term should be abolished, but until this happens archæologists should, at least, make some attempt to define its modern meaning. I would suggest that the name " Chellean " should be applied only to hand-axes, often of rostroid form, made by coarse, " free " flaking, in which symmetry of outline is not an outstanding feature, and possessing heavy butts and clearly defined wavy edges. It is evident that Professor Breuil in his recent paper (written in conjunction with Professor Koslowski) " Études de stratigraphie paléolithique dans le Nord de la France, la Belgique, et l'Angleterre ",[2] is realizing the necessity of this, and it is to be hoped that this paper marks a further step in putting the archæological house in order. If the term " Chellean " is to be applied in future only to hand-axes such as I have described, then I have no doubt that these specimens were made in the period, or periods, when the Cromer Forest Bed and the Stone Bed at its base were deposited, that they are to be found in these accumulations and not in those of later date, except in a derived condition. The other more symmetrical, approximately straight-sided hand-axes, made, as to their thin, blade-like anterior portions, by "controlled" flaking, to which also the term "Chellean" is applied by some archæologists, are never found in the deposits mentioned but are to be regarded as "Acheulean" implements belonging to a later interglacial epoch.

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[1] *Journal Anthr. Inst.*, 1921, July to December, 385–418.

[2] *L'Anthropologie*, t. xli, 1931.

I notice that, in his reference to the Baeton Valley Gravel, Dr. Solomon does not mention that flint implements have been found in this deposit.[1] It was from here that half a hand-axe of Acheulean type was discovered, but I did not know that, as claimed by Dr. Solomon, another has been found in the gravel surmounting the cliff at Lighthouse Hill, Cromer.

J. Reid Moir.

THE OATLAND (I.O.M.) IGNEOUS COMPLEX.[2]

Sir,—It has been brought to the notice of the authors of the above that no mention has been made of a paper[3] published in 1910, bearing on the same subject. In drawing up a list of works in this connection the usual precautions were taken to include everything within the reach of the average reader; and through being unaware of White's work the authors have made an interesting comparison possible, and it is gratifying to find that what was doubtful in their minds is corroborated by this independent investigation. There are no serious differences in the conclusions though the former worker seems convinced that a considerable interval elapsed between the intrusion of the basic and acid phases. Actually this is consistent with the then prevailing view that such contrast in composition could only be brought about by time. If such is the case why then should the granite be disposed concentrically within the basic rock? The influence of heat, greatest in the centre, is known to be of the highest importance in assisting the uprise of the later magma. But should the consolidated mass be entirely cool there is no cause for the second intrusion to follow a particular course and the granite at Oatland gives not the slightest indication of having arisen in anything but a definite channel within the basic rock and through that part which was obviously the hottest before emplacement was effected.

E. A. Gamba.

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[1] *Proc. P.S.E.A.*, iii, pt. ii, 219–243.

[2] J. H. Taylor and E. A. Gamba, *Proc. Geol. Assoc.*, xliv, 355–377.

[3] White, F. W. "Complex of Igneous Rocks at Oatland (Santon) Isle of Man," *Proc. Geol. Soc. Yorks*, 1910.